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A Literature Survey on Different Denoising Techniques in EMD –ECG - Using Different Filters

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Abstract : In this survey paper discuss the various Denoising technique in EMD –ECG and discuss the multiple filters. Electrocardiogram (ECG) conveys numerous clinical information on cardiac ailments. For the analysis of mutual coupling also focus on the surface current analysis, in this survey shows the surface current analysis of different previous work. In this survey paper also discuss about the Electrocardiogram (ECG) problem signals are crucial for diagnosing various cardiac abnormalities. However, these signals are often corrupted by various types of noise, including baseline wander, powerlines interference, and muscle artefacts these are the major problem in this survey paper. The last section discusses about the ECG signal or electrocardiogram is a widely used exam in cardiology field. It describes the electrical activity of the human heart and has a high clinical value for diagnosing cardiac arrhythmias**.**

Keywords— Space-Time Trellis Code (STTC), Filter, Inter-Carrier Interference, Bit Error Rate (BER), Signal To Noise Ratio (SNR) And Wireless Fading Channe.

I. INTRODUCTION

Electrocardiogram (ECG) is widely utilized tool for the identification of cardiovascular disorders. A typical ECG signal contains following segments, namely P, Q, R, S, and Twave. Due to the rapid growth of population, computer based automated ECG analyzer has a great importance. For reliable and efficient analyzing of ECG signal, a noise free ECG signal is much desired. However, practically during acquisition and transmission, several noises in particular, Gaussian noise, power line interference, muscle artifact, baseline wander, etc. contaminates with ECG signal. Gaussian noise is generated due to the poor channel condition, power line interference appears because of power supply, muscle artifact is introduced by the muscle activity and baseline wander is occurred due to respiration [5]. Elimination of these noises is very much essential for reliable analysis. Hence, the denoising of ECG signal through appropriate algorithms is an important topic in the field of biomedical engineering.

Several researchers contribute a number of research articles on ECG denoising technique, these methods are mainly based on digital filter bank [6, 7], adaptive filter [4], principle component analysis [8], neural network [9], Bayesian filter [10], discrete wavelet transform (DWT), empirical mode decomposition (EMD) [14], EMD+DWT [15, 16]. Digital filter based techniques require suitable cutoff frequency, moreover, they blur the signal by removing P and T waves [6, 7]. Adaptive filter and neural network based methods require additional reference signals and training phase [4, 9]. Bayesian filter based algorithms require complex mathematical calculations [10]. In EMD based denoising methods, the intrinsic mode functions (IMFs) are extracted from the signal [14, 15]. As the high-frequency artifacts are concentrated on only a few lower order IMFs so to discard the noise components and preserve QRS complexes, a window is applied. Then a partial reconstruction is employed by using the windowed IMFs and the others IMFs. As a result, the noises in the frequency range of QRS complex still exist. Hence, a further denoising procedure is essential.

Introduced an improved ECG denoising technique based EMD along with an adaptive switching mean filter (ASMF). The ASMF is commonly used for image denoising. It is inspired by the fact that, there should be a

similarity in value in neighborhood pixels. Here, at the primarystage, the corrupted ECG signal is decomposed into its IMFs and a wavelet denoising operation is performed on first three IMFs to reduce the high-frequency artifacts. Then, the signal is recovered by accumulating the denoised IMFs and remaining IMFs. Now, the ASMF is applied for further improvement of signal quality by reducing the noises those are spread in the lower frequency band. Due to the use of the ASMF, the peaks of the ECG signal are attenuated. Hence a peak restoration operation has been performed. For evaluation of the efficiency of the presented method standard ECG signals of MIT-BIH arrhythmia database have been utilized [17]. Three performance metrics Signal to noise ratio improvement (*SNRimp*), root mean square error (*RMSE*) and percentage root mean square difference (*PRD*) have been used. The efficacy of the presented work is compared with the existing methods.

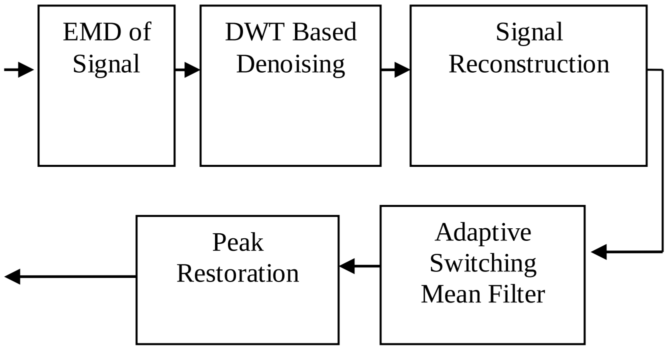

Figure 1. Block diagram of the presented ECG denoising technique

II. Literature Survey

***Talbi Mourad et.al. (2023)* –** Electrocardiogram (ECG) denoising based on Lifting Wavelet Transform (LWT) and Total Variation Minimization (TVM). This approach was proposed in the literature and its first step consists in applying twice the LWT to the noisy ECG signal in order to obtain two details coefficients, cD1 (at first level) and cD2 and one approximation coefficient cA2 (at second level). The two coefficients cD1 and cD2 are denoised by soft thresholding in order to have two denoised coefcients cDd1 and cDd2. The coefficient cA2 is denoised by TVM-based denoising technique in order to have a denoised coefficient cAd2. The last step of this proposed approach consists in applying twice the inverse of LWT (LWT^{-1}) to cDd1 and cDd2 and cA2 in order to obtain the denoised ECG signal. The proposed approach evaluation is performed by comparing it to three other denoising techniques introduced in the literature. [01].

Pavan G. Malghan et. al. (2023) –In this research work an improved VME technique for ECG signal denoising by combining the heap-based optimizer with the automatic wavelet interval-dependent thresholding technique. The method accurately estimated the optimal penalty factor α for the VME algorithm to extract PLI noise from the corrupted ECG signal. The envelope entropy spectrum as an objective function for the HBO optimization proved to have a fast convergence speed compared to PSO, GWO, and HGWO. Furthermore, AWIT helped to eliminate MA noise from the ECG data with greater efficiency leading to improved signal quality in terms of SNR, MSE, and CC. The results showed that our proposed method outperformed all existing algorithms. Our method may be effective for ECG signal denoising applications in cardiac health monitoring devices and help the physician or a doctor to diagnose the arrhythmias flawlessly. [02].

Ankita Shukla et.al. (2023) - In this research work Proactive illness diagnosis with AI and related technologies has been an intriguing and productive field in the last ten years. Cardiovascular illnesses are among the medical conditions that need regular monitoring. Arrhythmia, a type of coronary heart disease, is frequently observed by clinicians using electrocardiography (ECG). In humans, an ECG records electrical activity and cardiac rhythm. In recent decades, there has been a substantial surge in the use of neural networks to detect cardiovascular abnormalities. It has been shown that using the denoised signal as compared to the raw input signal increases the probability of better identification of arrhythmias. In this paper, rigorous, three-step preprocessing is done to improve classification accuracy. Firstly, denoising is done using a wavelet transform, then, for baseline artifact filtering, five filters have been applied to ECG signals, and lastly, an R peak is detected. A hybrid (CNN+LSTM) model is implemented to automate arrhythmia categorization on a denoised ECG signal. Comparative analysis demonstrates that the suggested model outperforms contemporary models in terms of various performance factors [03].

Anusaka Gon et.al. (2023) - In this research work the Noise removal is the most crucial pre-processing step for present-generation biomedical wearable electrocardiogram (ECG) patches and devices to provide efficient detection and monitoring of cardiac arrhythmias. This paper proposes a hardware-efficient and multiplier-less FPGA-based ECG noise removal architecture based on lifting-based wavelet denoising that employs a universal threshold level-dependent function in combination with soft thresholding to produce a noise-free ECG signal. The paper also proposes a modified lifting-based discrete wavelet transform (DWT) algorithm that is multiplier-less and provides a one-step equation for the calculation of the forward output coefficients and the inverse output coefficients. Since a comparator circuit is a very complicated circuitry in VLSI implementation, an optimized median calculation and soft thresholding block with no compare operations for wavelet-based thresholding is proposed. The ECG data is collected from the MIT-BIH arrhythmia database and the ECG noises from the MIT-BIH noise stress database. The proposed denoising technique for the ECG signal is tested on MATLAB which achieves an average improvement in SNR of 7.4 dB and an MSE of 0.0206 [04].

Mala Sinnoor et.al. (2022) - In this research work The Electrocardiogram signal (ECG) is highly susceptible to the electrical environment from where the motion artifacts were being recorded. The accurate representation of the ECG signal will necessitate removing the noise from various sources thereby resulting in a noise-free model. This present research work uses Multi scale Local Polynomial Transform (MLPT) technique that provides wavelet transform as an alternative when the MLPT model was non-equispaced. The proposed research combines two approaches such as MLPT and Ensemble Empirical Mode Decomposition (EEMD) forming a Hybrid Transform Model which is used for denoising in the research. The present research work considers white Gaussian noise and experimental results are based on the MIT-BIH Physionet Database. The results of the proposed hybrid MLPT-EEMD obtained better SNR values of 25.93 dB when compared to the existing Empirical Mode Decomposition technique (EMD) of 5.43dB, EMD with adaptive switching mean filter obtained 9.135 dB and S-Transform based Time–Frequency Filtering Approach obtained 13.82 dB [05].

Monisha Lodhi et.al. (2022) **-** In this research work The proposed threshold& shrinkage function is useful while processing ECG signal& to improve signal-to-noise ratio (SNR)for obtaining clean recordings & preserve original shape for signal, especially peaks, without distorting waves& segments. main job is to recover a true ECG signal from noisy recording& successfully achieved by proposed method.This thesis work is study of EMD based ECG signal de-noising and three research work have been studies and explained it's been observe that most of the available methods for ECG noise removal use EMD for ECG signal decomposition and later on different methods use different filters like [1] use switching mean filter [2] use adaptive filter and [3] monitor activity and normal FIR filter RMSE, SNR, PRD and standard deviation has been used for measurement of the results of the ECG signal filtering. [06].

Monisha Lodh et.al. (2022) **-** In this research work A variety of noise sources could tamper with an ECG signal. Power line interface noise, electrosurgical noise, instrument noise, and electromyography noise are all examples. An efficient method of removing unwanted noise from ECG readings is urgently required. Using an EMD in combination with an adaptive switching mean filter, we propose a new method for de-noising ECG data in this study. In contrast to conventional EMD based de-noising approaches, which only de-noise lower-order IMFs, ASMF operation has been applied to further improve signal quality in this investigation. The lower-order IMFs are filtered using the wavelet de-noising technique to keep the QRS complexes while lowering the high-frequency artefacts. To further enhance the signal quality, adaptive switching mean filtering (ASMF) is then performed. The given technique is evaluated by running tests on the MIT-BIH arrhythmia database. At different ratios of signal to noise (SNR), a Gaussian signal is added on top of the raw data [07].

Shahid A. Malik et.al. (2021) **–** In this research work During its acquisition phase an ECG signal gets adulterated with distinct variants of undesirable noise thereby degrading its qualitative nature thereby inflicting a restraint on its clinical applicability. Hence it becomes imperative to design efficient methods to remove these artifacts specifically without deteriorating the signal quality. From classical approaches to modern digital methods, a multitude of methods have been reported in the literature for this purpose. In this paper, we have employed a computer-based hybrid approach that scrutinizes the denoising potential of VMD method. It proceeds by disintegrating an ECG signal polluted with high frequency PLI and low frequency noise into a band of VMFs with PLI distributed over lower order modes while as the low frequency noise distributed over the higher order modes. The higher order modes are then separately fed to an SWT system while as the sum of the lower order modes is fed to a non-local mean filter. Finally, the signal is reconstructed from the processed modes to generate a pure ECG signal free from artefacts [08]

TABLE-1 COMPARISON OF DIFFERENT PREVIOUS METHODS

S. No	**Ref./Year**	**Authors**	**Title**	**Method**
1	[01]/2023	Talbi Mourad et.al .	An ECG Denoising Technique Based on LWT and TVM	Wavelet Transform denoising method
2	[02]/2023	Pavan G. Malghan et.al.	An Improved VME Technique via Heap Based Optimization Algorithm and AWIT Method for PLI and MA Noise Elimination in ECG	AWIT Method
3	[03]/2023	Ankita Shukla et.al.	Denoising ECG signals and their analysis using Hybrid Deep learning model	Hybrid Deep learning Method
4	[04]/2023	Anusaka Gon et.al	Design and FPGA Implementation of an Efficient Architecture for Noise Removal in ECG Signals Using Lifting-Based Wavelet Denoising	Lifting-Based Wavelet Denoising methods
5	[05]/2022	Mala Sinnoor et.al.	distributed DL-based attack detection framework	Hybrid MLTP-EEMD
6	[06]/2022	Jaya Prakash Alla m et.al	Patient-Specific ECG Beat Classification Using EMD And Deep Learning-Based,	EMD and deep learning-based technique
7	[07]/2022	Monisha Lodhi et.al.	Design Of Kalman Adaptive Filter Thresholding And EMD Based De-	Thresholding and EMD based De-noising

			Noising Method For ECG Signals	Method
8	[08]/2021	Shahid A. Malik et.al.	A VMD-SWT based ECG denoising technique	ECG denoising technique

III. ECG SIGNAL PROCESSING

The ECG signal or electrocardiogram is a widely used exam in cardiology field. It describes the electrical activity of the human heart and has a high clinical value for diagnosing cardiac arrhythmias [9]. From the ECG signal processing, several parameters can be extracted. As a rule, different waves' durations and shapes can indicate some cardiac abnormalities. Fig. 2 represents the formation of the ECG signal, which reflects the different deflections and contractions of the heart muscles, making it possible to diagnose a patient's cardiac state.

To make the best use of ECG data in large quantities, intelligent diagnostic systems have appeared. These systems can improve the quality of the signal; extract useful information, and offer a diagnosis that can help doctors make the right decisions.

The biomedical engineering revolution forces researchers to enhance the automatic diagnosis by optimization of ECG processing algorithms in order to ensure real-time monitoring of cardiac data; and their implementation on embedded systems as recent technological resources.

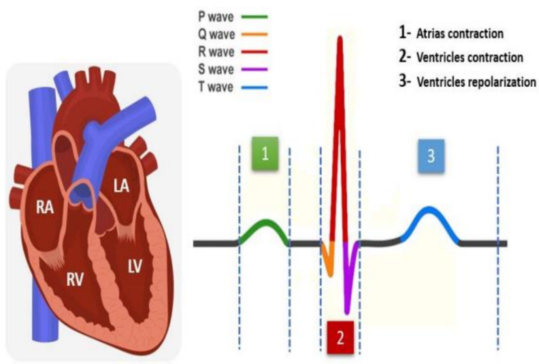

Figure 2. ECG Signal Formation

The ECG signal is characterized by low frequency and small amplitude. So, it is often affected by various kinds of noise as interference due to electrical appliances, high frequency noises produced by muscles activity, and low frequency noises of body movements in relation with respiration, which distorts its morphology, resulting a wrong diagnostic of the heart state of the patients [5,20]. To overcome this problem, the ECG signal must first go through a precise and effective pre-processing step.

The pre-processing step aims to remove or reduce the different noises. In this context, many methods are used such as Digital Filters (FIR/IIR) [21-22], Empirical Mode Decomposition (EMD) and Ensemble EMD (EEMD) based techniques, Discrete Wavelet Transform (DWT), Dual Tree Wavelet Transform (DT-WT) and Adaptive Filtering.

A. Related Works based ECG Denoising

Digital filters are represented by Finite Impulse Response (FIR) and Infinite Impulse Response (IIR). They are used to denoiseg ECG signals. Their names are originally linked to the mathematical definition, and their expressions are given respectively by (1) and (2):

$$Y(n) = \sum b(q)X(n-q) \qquad (1)$$

$$y(n) = \sum ak\ y(n-k) + \sum bk\ x(n-k) \qquad (2)$$

The implementation of FIR filters can be done without feedback as it is shown in Fig. 2 where X(n) presents the input signal, Y(n) is the filtered signal, Z -1 operator is a delay in the Z transformation, N is the filter order, and bq are the coefficients of the filter transfer function. Various windowing techniques are used, as example: Rectangular window, Kaiser.

window, Hamming window, Hanning window and Blackman window. IIR filters are designed using filters as Chebyshev filter, Butterworth filter, Inverse Chebyshev filter [30]. The major difference between them is that FIR filters are stable for any input signal. However, IIR filters can alter to unstable due to the feedback as shown in Fig. 3. Where an and bm are the filter transfer function coefficients.

Most of the works used FIR or IIR filters by selecting a bandwidth related to the utile data from the ECG signal. From different papers, it can be deduced that that FIR filter with Kaiser Window eliminates noises from ECG signal with less alteration in the waveform. FIR filters' problem is the high computational due to the number of coefficients needed to achieve excellent denoising result and a group of delay in response, which is the main challenge in real-time systems.

Wavelet methods have proven to be more common and effective than FIR/IIR filters. Wavelet methods simultaneously characterize time and frequency information. They decompose the signal to different resolutions using low pass filters (H[n]) to get the approximations (A) and high pass filters (g[n]) to get the details (D) as it's explained in Fig. 4. The ECG signals are denoised using thresholding techniques. But they have some limitations since they reduce the signal amplitude, which can affect the R waves. To overcome this limitation, methods based on EMD are used, the signal is disintegrated into a sequence of intrinsic mode functions (IMFs), and noisy IMFs are removed, but this technique can remove some useful information when eliminating the noisy IMFs.

EEMD is used to overcome this problem by removing the mode-mixing . To deal with the problems of complexity in ECG denoising, W. Jenkal et al. developed a new approach inspired from image denoising. This approach is an adaptive dual threshold filter which is dedicated to removing high-frequency noises this method aims to compute three elements for a selecting window (the average of the window, the higher threshold, and the lower threshold) and then the correction of the window's median value using the thresholding. The process is explained in the following block diagram shown in Fig. 4. The performance evaluation of this method is made in [8] based on the SNRimp result comparison between the ADTF and techniques based on EEMD. This evaluation shows that the ADTF gives very good results compared to the EEMD denoising algorithm presented in and a competitive SNRimp results to the enhanced EEMD method (EEMD-GA) published in. The main characteristic of the ADTF algorithm is its low complexity compared to the cited methods. The ADTF presents a linear complexity C(n) depending just on the signal size n. A comparative study of the complexity between the EMD, the EEMD, and the ADTF methods is presented in [8]. The conclusion of this study shows that ADTF presents a low complexity, unlike EMD and EEMD, which is related to various parameters, namely, the length of the signal, the number of the noisy signals, the number of IMFs, as well as the number of sifting processes. Comparing with the DWT, it also has linear complexity, in the manner of EMD/EEMD, it's related to other parameters not only the size of the signal, we are talking about the wavelet mother's coefficients, the number of decomposition's level and also the thresholding technique. In the next section, a detailed study of the ADTF is presented as well as simulation results.

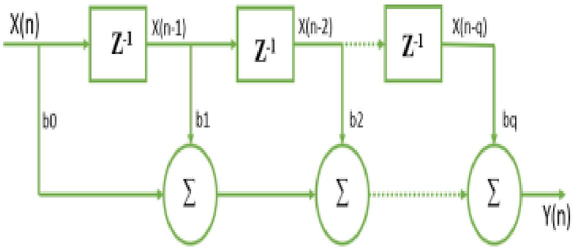

Figure 3 FIR Filter Conceptions

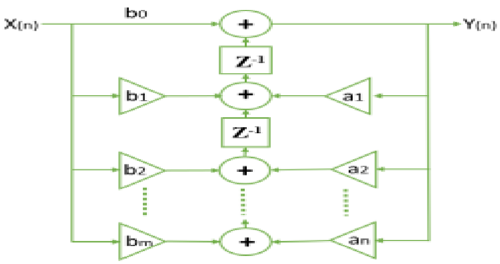

Figure 4 IIR Filter Conceptions

IV. PROBLEM STATEMENT

Electrocardiogram (ECG) signals are crucial for diagnosing various cardiac abnormalities. However, these signals are often corrupted by various types of noise, including baseline wander, powerlines interference, and muscle artefacts. The presence of noise in ECG signals can hinder accurate analysis and interpretation, leading to incorrect diagnoses and treatment decisions.

The Empirical Mode Decomposition (EMD) is a popular signal processing technique used for ECG denoising. EMD decomposes the signal into intrinsic mode functions (IMFs) that represent different frequency components. However, traditional EMD-based denoising methods suffer from limitations such as mode mixing and end effects, which can lead to distorted ECG signals and reduced denoising performance.

To address these limitations, an improved EMD-based ECG denoising method is proposed, incorporating an Adaptive Switching Mean (ASM) filter. The objective of this study is to enhance the denoising performance of EMD by effectively removing noise while preserving the important features of the ECG signal.

Problem with was that they never derive a new procedure they just study & select appropriate procedure from available methods as per input ECG signal its procedure is good if they use its procedure for research work however cannot guarantee to work accurate in practical conditions. develop its own procedure for Thres holding & uses single stage filtering problem is that if filtering done is not appropriate than accurate Thres holding will also produce wrong results & second, they use conventional Daubechies wavelet for Thresholding. The ECG signal is time varying signal, includes the valuable information related to heart diseases, but frequently this valuable information is corrupted by various noises. As noise corrupts the ECG signal it is very important as well as difficult task to suppress noises from ECG signal. So de-noising is the method of estimating the unknown signal from available noisy data. develop their own method for adaptive EMD filter and uses single stage filtering problem is that if the filtering done is not appropriate in one iteration of adaptive filter than inaccurate Threshold may also produce wrong results. Uses empirical mode decomposition (EMD) along with adaptive switching mean filtering (ASMF) based ECG de-noising technique, their method was good but ASMF was time consuming process which further reduces the threshold.

V. CONCLUSION AND DISCUSSION

In this survey paper discuss on different Denoising and multiple filters. In this work EMD based denoising approaches, where only lower orders IMFs are denoised in this work, along with EMD, ASMF operation has been employed for further signal quality improvement. The lower order IMFs are filtered through wavelet denoising technique to reduce high-frequency artifacts and retain the QRS complexes. Then considering the effectiveness of ASMF, for further enhancement of signal quality adaptive switching mean filtering is performed. In this survey paper observe that the Electrocardiogram (ECG) signals are crucial for diagnosing various cardiac abnormalities. However, these signals are often corrupted by various types of noise, including baseline wander, powerlines interference, and muscle artefacts.

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