An Adaptive ECG Noise Removal Process Based on Empirical Mode Decomposition (EMD)

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Introduction

- The electrocardiogram (ECG) is a common diagnostic tool for heart problems. It represents the electrical activity of the cardiovascular system. The true status of the heart can be discovered by mining extensive information from each section. Nonetheless, for accurate ECG signal feature extraction, noise-free and high-quality signals are usually required.
- This research proposes an adaptive ECG noise removal technique utilising empirical mode decomposition (EMD). The proposed technique employs mean value adaptive biasing to lower the first and second Intrinsic Mode Functions (IMF) components, and then reconstructs the original signal from the non-modified and modified IMFs.
- The Simulations and investigations indicated that the proposed ECG noise filtering technique outperforms current approaches. A thorough examination of the results suggests that the proposed technique can be utilised as a tool for noise reduction in ECG signal pathology.

Material and Methods

In this paper, an adaptive technique based on EMD to eliminate ECG noise is proposed, each ECG record is subjected to 100 simulations at all input SNR levels, with the mean of all outcomes suitably analysed. Description of the recommended approach is given in Figure 1.

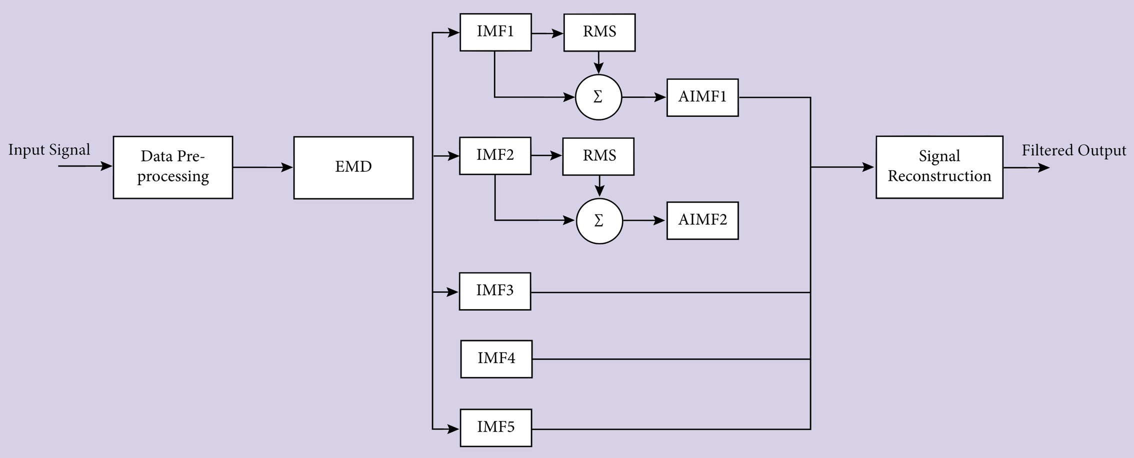


Figure 1. The Proposed Method

1. Database
Datasets signals of ECG extracted from the MIT-BIH arrhythmia database and BUT QDB (Brno University of Technology ECG Quality Database).

2. Empirical Mode Decomposition - EMD
EMD is a novel signal processing technique for nonlinear, multicomponent, and nonstationary time series decomposition.

3. Baseline Wander Correction (BW)
Baseline Wander correction is an important step in processing of ECG signals because BW makes interpretation of ECG recordings difficult.

4. Elimination of Power Frequency
The primary notion behind power line removal using EMD is to undertake selective reconstruction of the ECG from the IMFs, accomplished through the use of a computer.

5. Data Reconstruction
The steps are explained bellow:

a. Calculating of the increasing mean pertaining to the IMFs. The calculation as follow:

$$R_k = Mean[\sum_{i=1}^{k}]f(i)] \quad (1)$$

b. Creating the confirmative test of the signal strength of each IMF.

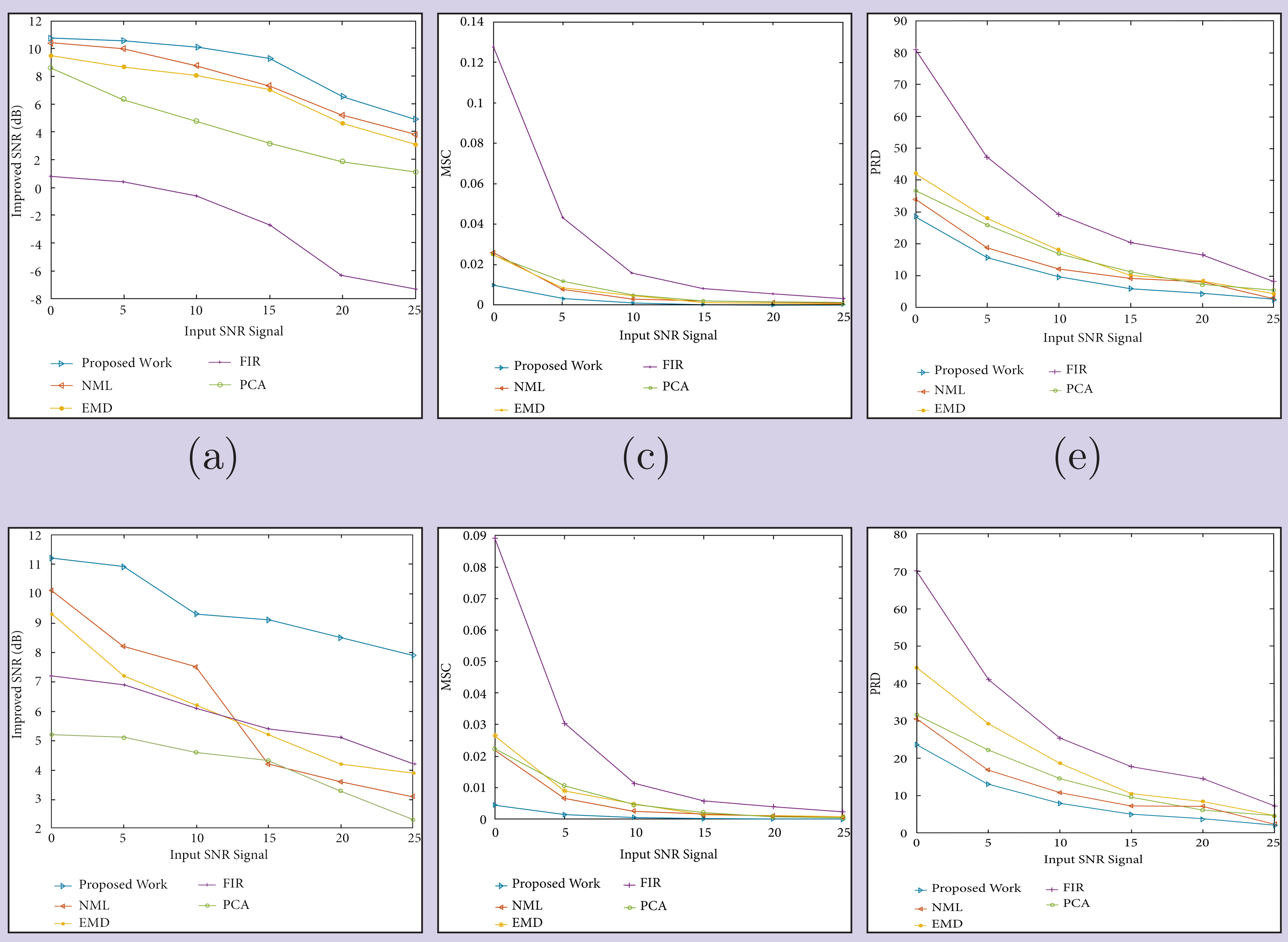
c. Reconstructing ECG signals by adding IMFs vectors in the following manner:

$$E\hat{C}G = \sum_{l=1}^{r} IMFs_l \quad (2)$$

where l is the IMFs number.

Result and Discussion

In the study, the signals contain both abnormal and normal ECG beats with time-varying QRS morphology. Then, adding three virtual noises, namely, electromyogram (EMG) noise, white Gaussian noise, and main line interference at various SNR decibel (dB) levels ranging from 0 to 25 in 5 dB steps. The evaluation considers three performance metrics: mean square error (MSE), output signal-to-noise ratio (SNR) enhancement, and percentage root mean square difference (PRD).
The SNR defines the signal energy based on the energy levels of the related noise. Since the goal of the analysis is to eliminate noise from ECG signals, a rise in SNR can be used to evaluate the filter's effectiveness, also it determines error signal energy while filtering. As a result, a lower MSE values indicate better signal estimation and retention of signal information.



(a) (c) (e)
(b) (d) (f)

Fig. 2. (a) The Improved SNRs Obtained for EMG Noise-degraded; (b) The Output SNR Levels of Denoised ECG Signals (Gaussian Noise Effect); (c)The MSE Comparisons of Numerous ECG Denoising; (d) The MSE Values of the ECG Signals Noise Filtering at Various Input SNR Levels; (e) The PRD Value Evaluation of Signal Recovery in the Case of EMG Noise Corruption; (f) The Routine Comparison of the PRD Values for Gaussian White Noise.

Figure a shows that for all input SNR values, the proposed technique outperforms the others while Figure b indicates that the proposed algorithm achieves a greater SNR than the other algorithms. In the case of EMG noise corruption, Figure c provides MSE comparisons of various ECG noise filtering algorithms and Figure d illustrates that the suggested method has a lower denoised signal MSE than other techniques. Figure e shows that the proposed method obtains lower PRD values across all input SNR levels, meaning that it is better at reducing EMG noise in ECG signals. The suggested method produces reduced PRD values at all input SNR levels, implying that clinical information is better preserved in filtered signals with lower distortion, as shown in Figure f.

Conclusion

In this research, an adaptive ECG denoising process derived from EMD is proposed. The main goal of this research is to enhance the conventional technique of relying on EMD for ECG denoising by utilising adaptive calculation of lower IMF mean values in the reconstruction of original signals.
The three performance evaluation parameters SNR, PRD, and MSE are utilised to assess the efficiency of the proposed method. The simulations and analysis indicated that the suggested ECG noise filtering strategy outperforms the current approaches. An analysis of the results suggests that the proposed technique can reduce noise in ECG signal pathology.

References

[1] Ahmed F. Hussein, Warda R. Mohammed, Mustafa Musa Jaber, and Osamah Ibrahim Khalaf. An adaptive ecg noise removal process based on empirical mode decomposition (emd). *Contrast Media and Molecular Imaging*, 2022, 2022.