Comparative Analysis of R-peak detection performance using Novel Wavelet Denoising (WD) with Empirical Mode Decomposition (EMD) Method

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ABSTRACT

Aim: R-peak recognition is vital in electrocardiogram (ECG) signal investigation. This examination proposed a comparative analysis of R-peak identification execution in ECG signal denoising using Novel Wavelet Denoising (WD) with Empirical Mode Decomposition (EMD). **Materials and Methods:** The performance analysis of the proposed R-peak detection method was tested on the MIT-BIH database. Comparative analysis of R-peak detection is performed by Empirical Mode Decomposition (EMD) where number of samples (N=10) and Novel Wavelet Denoising (WD) Classifier where number of samples (N=10) techniques with pre-test power of 80 %. **Results:** The accuracy rate of Empirical Mode Decomposition (EMD) is 98.15% whereas results of Novel Wavelet Denoising (WD) accuracy rate is 97.11%. The Predictivity rate is 98.72% for Empirical Mode Decomposition (EMD) whereas the results of Novel Wavelet Denoising (WD) Predictivity rate are 96.20%. The Sensitivity rate is 98.62% for Empirical Mode Decomposition (EMD) whereas results of Novel Wavelet Denoising (WD) Sensitivity is 94.05%. There is a significant difference in Accuracy rate (P=0.051). The results obtained were considered to be error-free since it was having the significance value $p < 0.05$ in SPSS Statistical analysis. **Conclusion**: Empirical Mode Decomposition (EMD) Classifier performs significantly better in finding the accuracy, predictivity and sensitivity for R-peak detection systems when compared to Novel Wavelet Denoising (WD) Classifier.

Keywords: ECG, Empirical Mode Decomposition (EMD), R-Peak Detection, Novel Wavelet Denoising (WD), Signal Denoising.

INTRODUCTION

Heart disease is one of the main diseases that threaten human health. The electrocardiogram (ECG) signal is one of the most important and well-known biological markers used to diagnose human health. The removal of the ECG signal feature is an adherence point for analysis and diagnosis. Accuracy of R-peak detection determines the diagnosis and treatment of the sufferer (Sadaphule, Mule, and Rajankar 2012). The detection of QRS complexity is one of the most important components of ECG signal analysis (Saritha, Sukanya, and Narasimha Murthy 2008). The detection of QRS, especially the detection of R peak in the heart signal, is easier than other parts of the ECG signal due to its structure and high altitude (Sasikala and Wahidabanu 2010; Nagendra, Mukherjee, and Kumar 2011).

Recently a lot of research has been done on R-peak detection performance in ECG signal denoising using Empirical Mode Decomposition (EMD) method. IEEE Xplore published 65 research papers, and Google Scholar found 53 articles. The Pan and Tompkins strategies (PT) (Pan and Tompkins 1985) seem, by all accounts, to be the most well-known benchmark given that they join a few essential procedures including low-pass separating, high-pass shifting, subsidiary shifting, figuring out, and windowing for the recognition of the R peaks. Shannon energy with the Hilbert change strategy (SEHT) (Manikandan and Soman 2012) gives great precision for identifying R-peak. Nonetheless, the Hilbert change in SEHT requires huge memory and handling time, making it unsatisfactory for continuous application. Zhu and Dong (Zhu and Dong 2013) fostered a R peak discovery technique called PSEE by utilizing just the SEE. The creators utilized a sufficiency limit that influences the presentation of the calculation for legitimate pinnacle identification. In (Pang and Igasaki 2018), authors applied improvement techniques from PC designs for information decrease, in light of the perception that the ECG is basically a graphical portrayal of heart electrical action. A four phase R peak location technique which executes nonlinear change and a discovering procedure is introduced in (Kathirvel et al. 2011). In (Chanwimalueang, von Rosenberg, and Mandic 2015), the closeness between a format QRS example and potential QRSs is misused using a coordination with channel, while the Hilbert change is utilized for the R peak confinement.Previously our team has a rich experience in working on various research projects across multiple disciplines(Ezhilarasan et al. 2021; Balachandar et al. 2020; Muthukrishnan et al. 2020; Kavarthapu and Gurumoorthy 2021; Sarode et al. 2021; Hannah R et al. 2021; Sekar, Nallaswamy, and Lakshmanan 2020; Appavu et al. 2021; Menon et al. 2020; Gopalakrishnan et al. 2020; Arun Prakash et al. 2020)

The existing technique for R-peak identification in ECG signals is used as Wavelet Denoising method. The main problem of the existing method is that ECG frequency spectra are quite overlapping with that of the noise spectra, especially because of the presence of QRS perplexing as a high frequency part in ECG. The aim of the research work is to propose a robust technique for the discovery of ECG trademark wave limits utilizing Empirical Mode Decomposition (EMD) in comparison with Novel Wavelet Denoising (WD).

MATERIALS AND METHODS

This work was carried out in the Digital Image Processing Laboratory, Department of Electronics and Communication Engineering, Saveetha School of Engineering, SIMATS, Tamil Nadu, and India. The MIT-BIH data set (Moody and Mark 2001) contains 50 ECG records; each record contains 25 min and was inspected at 360 Hz. There are two leads in each record and the main lead was utilized in the trial. Areas of R-peaks have been explained by at least two cardiologists freely for all records. Sample size was calculated by using previous study results. The output is obtained by using MATLAB programming Language. A sample dataset of both proposed and existing methods are exported to Microsoft Excel document for verification using statistical analysis software (SPSS IBM tool) as an input. To train these datasets, required a monitor with resolution of 1024×768 pixels (CPU 7th gen, i5, 4 8GB RAM, 500 GB HDD), and Matlab software with required library functions and tool functions. The calculation is performed utilizing G-power 0.8 with alpha and beta qualities 0.05, 0.2 with a confidence interval at 96%.

Sample Preparation Group 1 Empirical Mode decomposition is a new method of processing signals used for the indirect, non-stationary time series decay. It is different from Fourier Transform (FT) or Wavelet Transform (WT) because the basic functions are available directly to the signal under test. In the analysis of a priori base such as FT or WT, the harmonics are certainly similar to the primary function in one form or another. IMFs must have two basic characteristics (1) they have the same value of extrema and zero-crossing or are very different each and (2) they are equal in terms of the definition of zero area. Empirical Mode Decomposition (EMD) is a signal examination strategy which consists of breaking down non-stationary signals into little or limited numbers of segments which are named as natural mode functions (IMF) (Mabrouki, Khaddoumi, and Sayadi 2014). There are two conditions for example fulfilled by IMFs.

1. The quantity of zero intersections and number of outrageous should contrast by one.

2. Anytime, the mean worth of the envelope by the neighborhood maxima and the envelope characterized by the nearby minima is zero. IMFs utilize moving cycle which is described as-:

a. The limit of sign $z(t)$ should be distinguished and maxima and minima of the sign is removed appropriately.

b. The calculation of the upper (emaximum) and the lower envelopes (eminimum) for the maxima and minima introduction is done through cubic spline lines.

c. Processing the normal of upper and lower envelopes is shown in Equation (1)

$$a1(t) = (eminimum(t) + emaximum(t))/2 \qquad (1)$$

d. The distinction determined is given by Equation (2)

$$b1(t) = z(t) - a1(t) \qquad (2)$$

e. By rehashing stages a-d until the subsequent sign meets the two measures of a IMFs another b1 (t) is taken by the Equation (3)

$$c1(t) = z(t) - d1(t) \qquad (3)$$

Sample Preparation Group 2 Novel Wavelet Denoising (WD) is a signal analysis tool that can simulate spectral and temporal information simultaneously from heavy signals, including an ECG. It defeats some of Fourier's widely used modification modes, which contain only spectral data globally, and has the ability to hide features created within the signal. Wavelet analysis has been applied to natural data including electroencephalogram, electromyogram, acoustic signals, and ECG. (Sahambi, Tandon, and Bhatt 1997; Li, Zheng, and Tai 1995). A complete analysis of the signal requires the removal of both the frequency and the temporary location of the signal components. As a result of the infinite scope of Fourier integration, the analysis is intermediate. This provides a complex space, even stationary signals.

Statistical Analysis

For statistical implementation, the software tool used here is IBM SPSS V26.0 (Pallant 2020). The independent variable in this analysis is the frequency of the particles in the algorithms, and the dependent variables are the accuracy, sensitivity, and specificity. The analysis was done with the sample data using an independent sample test.

RESULTS

Figure 1 shows R-peak detection performance in ECG signal denoising using Novel Wavelet Denoising (WD) filter with Empirical Mode Decomposition (EMD). For comparing the performance of the Wavelet Denoising (WD) Classifier in which the Empirical Mode Decomposition (EMD) shows higher values in all aspects of parameters.

Figure 2 shows the Accuracy Rate of Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD) Classifier. Empirical Mode Decomposition (EMD) has higher values in terms of accuracy rate compared with Wavelet Denoising (WD). Variable results with an accuracy rate of 98.15% for Empirical Mode Decomposition (EMD) whereas results of Wavelet Denoising (WD) accuracy rate are 97.11%.

Figure 3 shows the Predictivity of Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD) Classifier. It represents the Empirical Mode Decomposition (EMD) having higher values in terms of Predictivity comparison with Wavelet Denoising (WD). Variable results with a Predictivity rate of 98.72% for Empirical Mode Decomposition (EMD) whereas results of Wavelet Denoising (WD) Predictivity rate are 96.20%.

Figure 4 shows the Sensitivity of Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD) Classifier. It represents the Empirical Mode Decomposition (EMD) having lower values in terms of Sensitivity comparison with Wavelet Denoising (WD). Variable results with a Sensitivity rate of 98.62% for Empirical Mode Decomposition (EMD) whereas results of Wavelet Denoising (WD) Sensitivity rate are 94.05%.

Table 1 portrays the Evaluation Metrics such as Accuracy Rate, Predictivity and Sensitivity of Empirical

Mode Decomposition (EMD) and novel Wavelet Denoising (WD) Classifier in which the Empirical Mode Decomposition (EMD) shows higher values in all aspects of parameters.

Table 2 shows the statistical calculation such as mean, standard deviation and standard error mean for Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD). Accuracy rate parameter used in the t-test. The mean accuracy rate of Empirical Mode Decomposition (EMD) is 98.15% and Wavelet Denoising (WD) is 97.11%. The Standard Deviation of Empirical Mode Decomposition (EMD) is 0.87762 and Wavelet Denoising (WD) is 1.7823. The Standard Error mean of Empirical Mode Decomposition (EMD) is 0.32140 and Wavelet Denoising (WD) is 0.6432.

Table 3 displays the statistical calculations for independent samples tested between Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD). The significance for accuracy rate is 0.051. Independent samples T-test is applied for comparison of Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD) with the confidence interval as 95% and level of significance as 0.69595. This independent sample test consists of significance as 0.001, significance (2-tailed), mean difference, standard error difference, and lower and upper interval difference.

DISCUSSION

Empirical Mode Decomposition (EMD) Classifier performs significantly better in finding the accuracy (98.15 %) and Predictivity (98.72 %) for R-peak detection systems when compared to the Novel Wavelet Denoising Classifier with accuracy (97.11 %) and Predictivity (96.20 %). The results obtained having the significance value $p < 0.05$ in SPSS Statistical analysis.

In the past research, the most important Empirical Mode Decomposition (EMD) and wavelet Denoising Filter classifiers are used for predicting the analysis of R-peak detection systems, where it is considered to specify the measurement specification (Blanco-Velasco, Weng, and Barner 2008). The proposed model exhibits Empirical Mode Decomposition (EMD) and wavelet denoising in which the Empirical Mode Decomposition (EMD) classifier has the highest values. The calculation is tried with beats of various cardiovascular conditions as a heart issue brings about an adjustment of thump morphology. Typical cardiovascular musicality, Myocardial Infarction (MI), Bundle Branch Block (BBB), Hypertrophy, Dysrhythmia beats are taken from PTB data set and Premature Ventricular Contraction (PVC) and some BBB information are taken from MIT-BIH data set. The accuracy rate of Empirical Mode Decomposition (EMD) is 98.94 % compared with wavelet denoising, which has an accuracy rate of 97.21 % (Hadj Slimane and Naït-Ali 2010) The structure of the modified information box takes into account the intermediate, minor and major attributes, interquartile access and malfunction (focus beyond the upper and lower extremities). The accuracy rate of Empirical Mode Decomposition (EMD) is 95.94 % compared with wavelet denoising, which has an accuracy rate of 92.21 % (Zhang et al. 2007). The Predictivity value for Empirical Mode Decomposition (EMD) is 98.93 % compared with the Denoising filter that has 97.20 %. The technique is tried with ECGs of various cardiological conditions with a decent identification affectability and particularity as displayed in the outcomes. The Sensitivity percentage for Empirical Mode Decomposition (EMD) is 98.33 % compared with a denoising filter that has 97.05 % (Slimane and Naït-Ali 2010). There are no opposite findings related to this research.

The limitation of this study is to predict the correct IMF level of noise reduction. Since each IMF is a filter-like output, it makes sense to expect a predictable IMF level of ECG noise reduction. The future work is to develop a system which can accurately detect the IMF level for noise reduction.

CONCLUSION

Two different methods for R-peak detection were evaluated using Performance parameters and it is found that the Empirical Mode Decomposition (EMD) classifier has the Accuracy rate of 98.15% which is higher compared with Wavelet Denoising (WD) method that has an accuracy rate of 97.11% and is significantly better in analysis of R-peak detection system.

DECLARATION

Conflicts of Interest

No conflict of interest in this manuscript

Author Contributions

Author KBI was involved in data collection, data analysis & manuscript writing. Author RN was involved in conceptualization, data validation, and critical review of manuscripts.

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TABLES AND FIGURES

Table 1. Evaluation Metrics (Accuracy Rate, Predictivity, and Sensitivity) of Wavelet Denoising (WD) and Empirical Mode Decomposition (EMD)

GROUP STATISTICS			
METHOD	**ACCURACY**	**PREDICTIVITY**	**SENSITIVITY**
Wavelet Denoising (WD)	97.11%	96.20%	94.05%
Empirical Mode Decomposition (EMD)	98.15%	98.72%	98.62%

Table 2. The statistical calculation such as mean, standard deviation and standard error mean for Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD). Accuracy rate parameter used in the t-test. The mean accuracy rate of Empirical Mode Decomposition (EMD) is 98.15% and Wavelet Denoising (WD) is 97.11%. The Standard Deviation of Empirical Mode Decomposition (EMD) is 0.87762 and Wavelet Denoising (WD) is 1.7823. The Standard Error mean of Empirical Mode Decomposition (EMD) is 0.32140 and Wavelet Denoising (WD) is 0.6432.

Group		**N**	**Mean**	**Standard Deviation**	**Standard Error Mean**
Accuracy Rate	Wavelet Denoising (WD)	10	97.11	1.7823	0.6432
	Empirical Mode Decomposition (EMD)	10	99.94	0.87762	0.32140

Table 3. The statistical calculations for independent samples test between Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD). The significance of accuracy rate is 0.051. Independent samples T-test is applied for comparison of Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD) with the confidence interval as 95% and level of significance as 0.69595. This independent sample test consists of significance as 0.001, significance (2-tailed), mean difference, standard error difference, and lower and upper interval difference.

Group		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval (Lower)	95% Confidence Interval (Upper)
Accuracy Rate	Equal variances assumed	6.435	0.051	16.234	18	.001	11.786	0.87651	11.23451	13.1234
	Equal variances not assumed			9.123	12.261	.001	11.786	0.87651	10.45321	13.1234

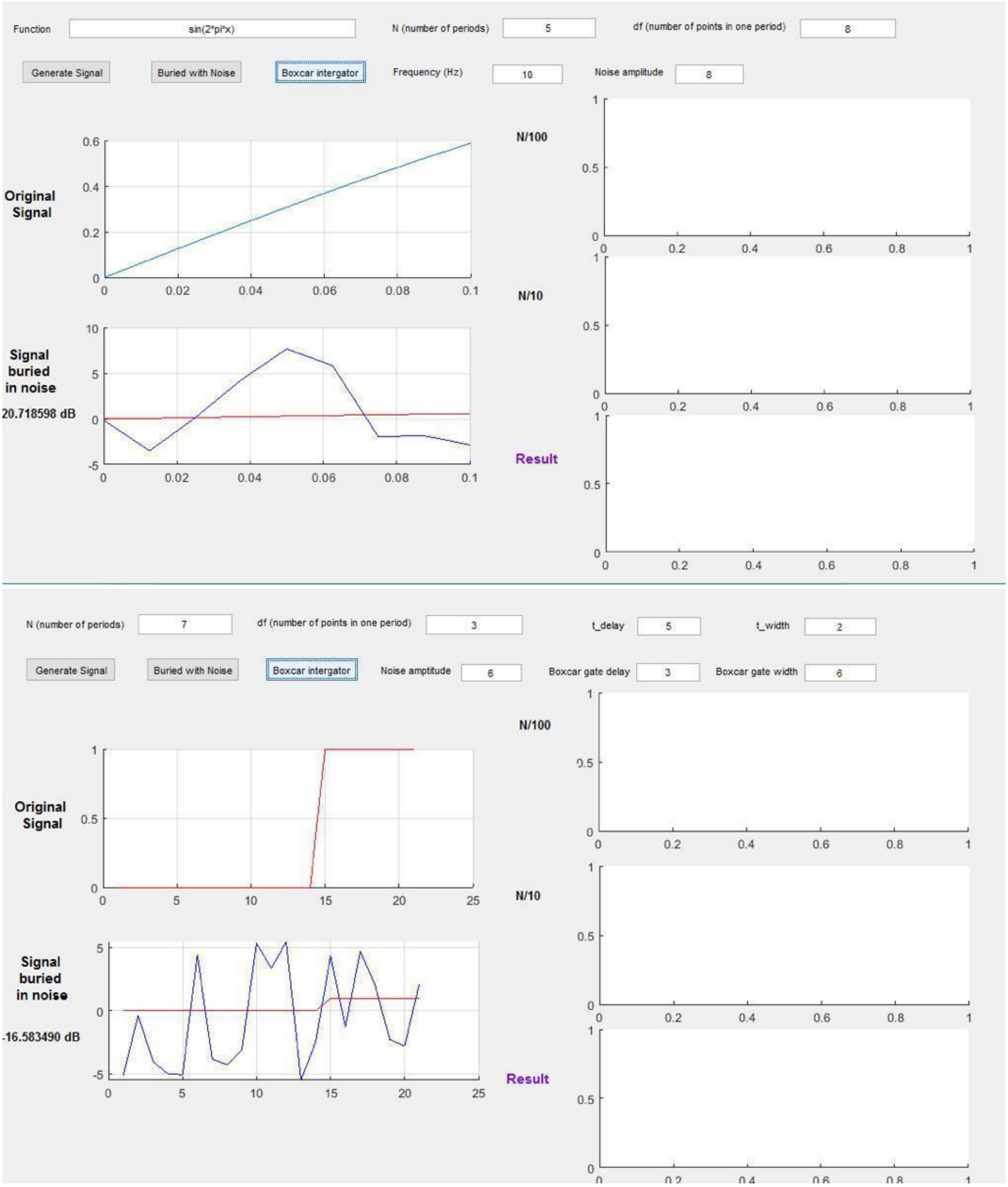

Fig. 1. R-peak detection performance in ECG signal denoising using Wavelet Denoising (WD) filter with Empirical Mode Decomposition (EMD).

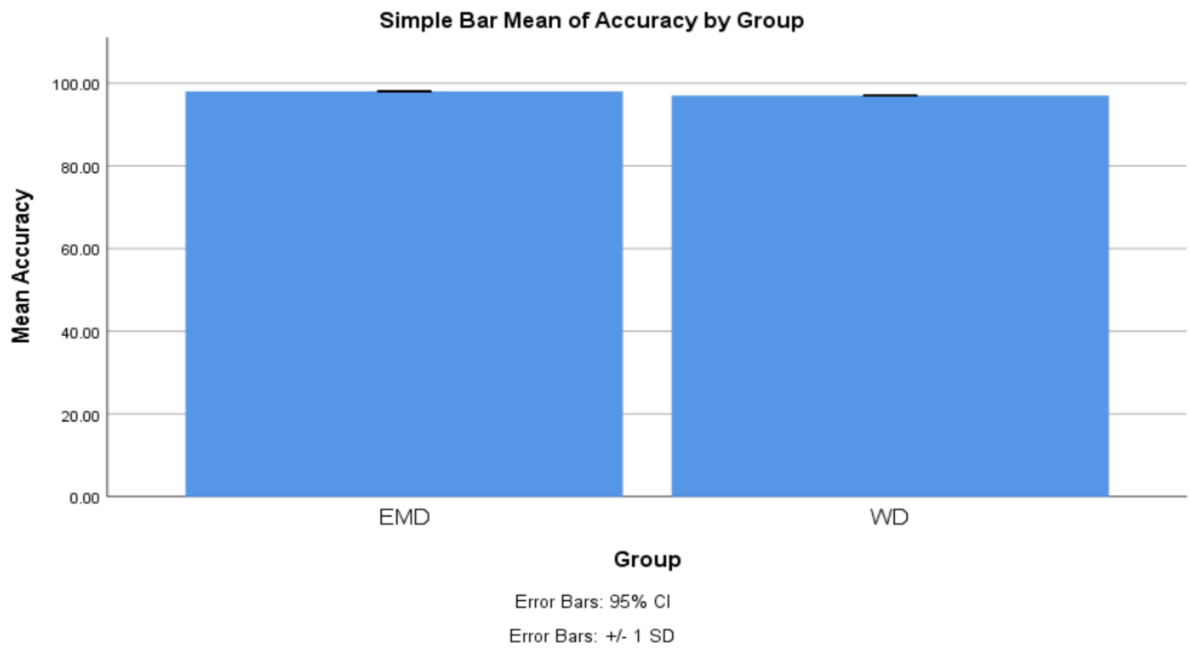

Fig. 2. Group Statistics (Accuracy Rate %) of different Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD) Classifiers.X-Axis: EMD vs Novel Wavelet Denoising. Y-Axis: Accuracy Rate, Deviation is ±1SD. The Empirical Mode Decomposition (EMD) is higher in terms of accuracy parameter when compared withWavelet Denoising (WD). Variable results with its accuracy rate of 98.15% for Empirical Mode Decomposition (EMD) whereas results of Wavelet Denoising (WD) accuracy rate of 97.11%.

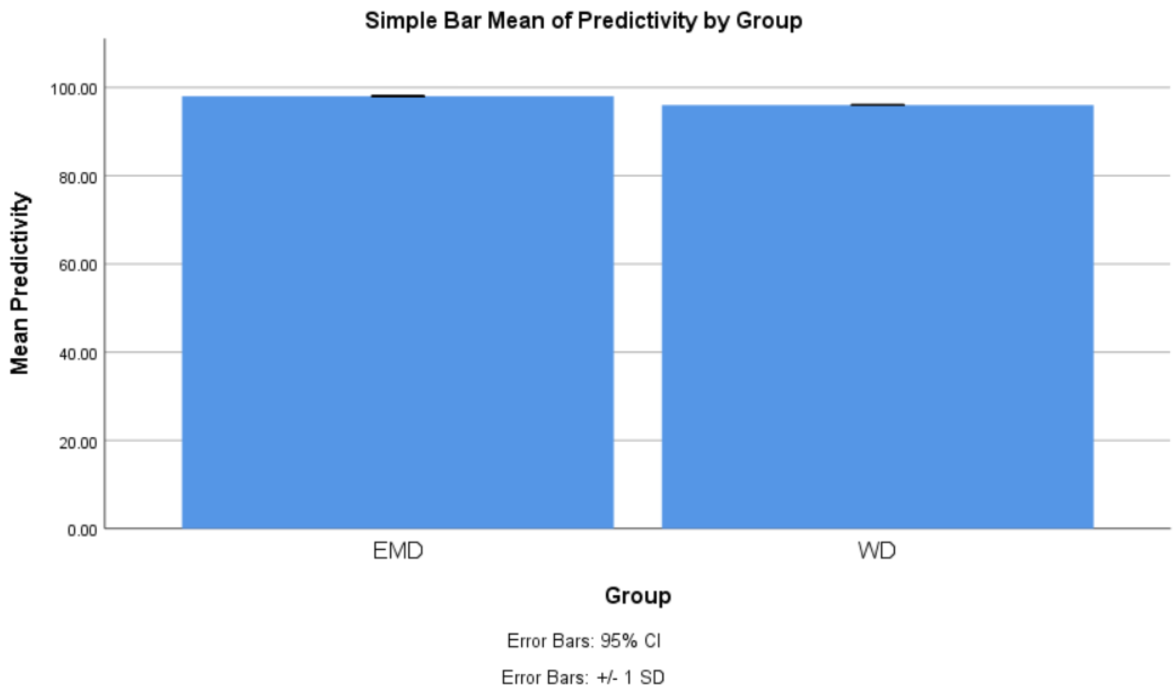

Fig. 3. Group Statistics (Predictivity) of different Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD) Classifiers.X-Axis: EMD vs Novel Wavelet Denoising. Y-Axis: Predictivity, Deviation is ±1SD. The Empirical Mode Decomposition (EMD) is higher in terms of Predictivity parameter when compared with Wavelet Denoising (WD). Variable results with a Predictivity rate of 98.72% for Empirical Mode Decomposition (EMD) whereas results of Wavelet Denoising (WD) Predictivity rate are 96.20%.

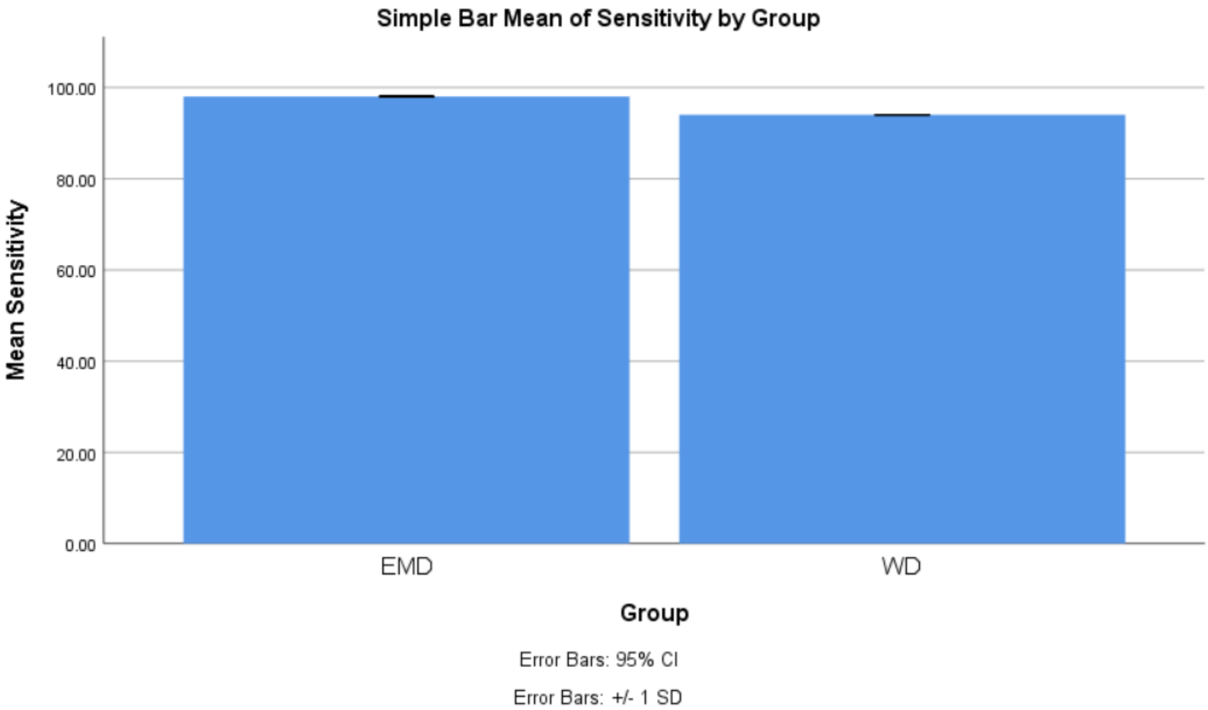

Fig. 4. Group Statistics (Sensitivity) of different Empirical Mode Decomposition (EMD) and Wavelet Denoising (WD) Classifiers.X-Axis: EMD vs Novel Wavelet Denoising. Y-Axis: Sensitivity, Deviation is ±1SD. The Empirical Mode Decomposition (EMD) is higher in terms of Sensitivity parameter when compared with Wavelet Denoising (WD). Variable results with a Sensitivity rate of 98.62% for Empirical Mode Decomposition (EMD) whereas results of Wavelet Denoising (WD) Sensitivity rate are 94.05%.