Analysis and Comparison of ECG Signal Quality Assessments Methods

Ramesh Babu Chukka and Ch. Sumanth Kumar

Abstract An ECG, SQA plays an important role in significantly improving the performance. However, in real cases, artifacts often corrupt. In this paper, several methods have been analyzed for ECG enhancement like fast Fourier transforms (FFT), empirical mode decomposition (EMD) and Hilbert vibration decomposition (HVD) based filtering. These methods are able to remove both high frequency and baseline wander noises. The method is validated through experiments on the PhysioNet/MITBIHA database records. Techniques are compared in terms of correlation, SNR and detection error rate. The simulation shows that the HVD-based filtering method provides a very good result for denoising and BW removal. In addition, we analyzed two types of SQA algorithms features and rules-based method and filtering and threshold-based signal quality assessment methods, which are intended to assess reliable heart rates and the good quality of ECG signal. The proposed methods are well suited for transmitting valid data for cloud diagnosis.

Keywords Electrocardiogram · ECG noises · Signal quality assessment

1 Introduction

Health is a primary need in our life. We are facing problems in getting proper health care because of limited technology and resources. All of ECG applications such as cardiovascular diseases diagnosis, arrhythmias recognition, sudden cardiac arrest prediction, highly demands the exact determination of ECG signal [1].

R. B. Chukka (✉)
Department of Electronics and Communication Engineering, Vignan's Institute of Engineering for Women, Visakhapatnam, India
e-mail: rameshbabuchukka@gmail.com

Ch. S. Kumar
Department of Electronics and Communication Engineering, GITAM Institute of Technology, GITAM Deemed to Be University, Visakhapatnam, India

S. Choudhury et al. (eds.), *Intelligent Communication, Control and Devices*,
Advances in Intelligent Systems and Computing 989,
https://doi.org/10.1007/978-981-13-8618-3_90

Challenges faced in the field of long-term healthcare monitoring include portability in size, weight, and low cost [2]. Noise-free signals are required for analysis, therefore, highly demanded for SQA in reducing the false alarms. The corrupted information may lead to the wrong diagnosis.

In this paper, we aimed to remove of baseline wander and high-frequency noises based on FFT, EMD, and HVD-based filtering technique is introduced. In addition, quality assessment strategies have been employed to tackle false alarms problems.

2 Methods and Methodology

For the implementation, ECG records are taken from standard databases as shown in Fig. 1.

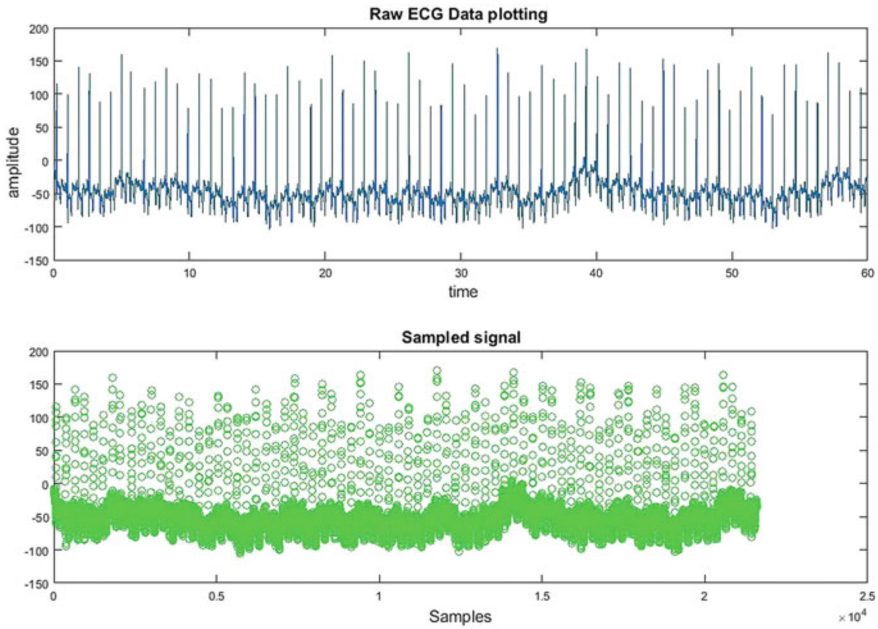

Fig. 1 Raw ECG data plot and sampled signal

2.1 ECG Denoising and Component Analysis

2.1.1 DWT-Based Filtering

Wavelet transform (WT) provides more information and can perform analysis of both frequency and time representation. An algorithm is used to compute the discrete WT (DWT) decompositions using LPFs and HPFs [3]. Figure 2 shows the BW removal using wavelet decomposition.

2.1.2 EMD-Based Filtering

An empirical mode decomposition (EMD) is introduced by Huang is used to analyze both time–frequency analysis.

Given an input signal x(t), the effective algorithm of EMD can be summarized as follows:

1. Identify all IMFs of x(t);
2. Generate the upper and lower envelope by connecting the maxima and minima;
3. Compute the local mean;
4. Extract the details;
5. Iterate on the residual.

The EMD method expresses the signal x(t) as the sum of a finite number of IMFs and a final residual is obtained at the end of process.

The output of the EMD Technique is shown in Fig. 3.

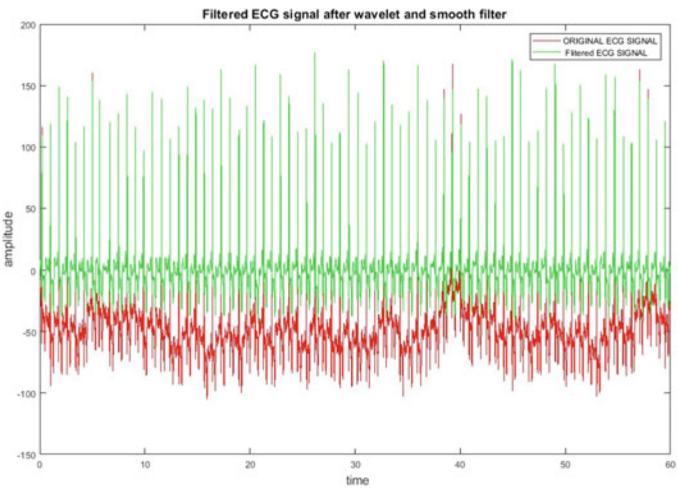

Fig. 2 DWT-filtered signal

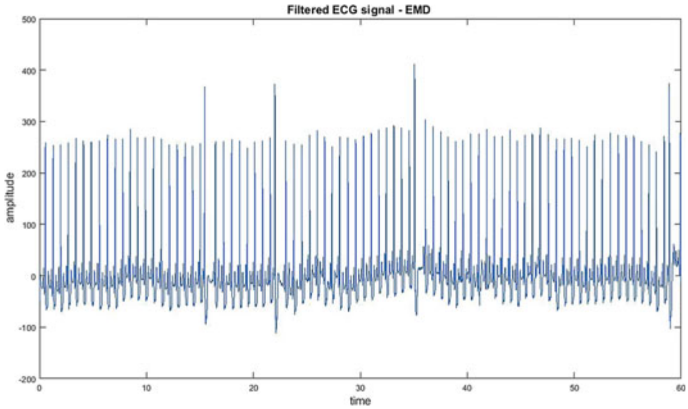

Fig. 3 EMD-filtered signal

2.1.3 HVD-Based Filtering

For better understanding, let we go with some mathematical issues.

(a) Estimation of the instantaneous frequency:

Let us consider a signal x(t) can be expressed as

$$x(t) = \sum_{l} a_1(t)\cos\left(\int \omega_l(t)dt\right)$$

where
a_1 (t) is the instantaneous amplitude and
ω_l (t) is the instantaneous frequency of l component.

(b) The Envelope Detection:

We choose a technique well-known synchronous detection to extracts the amplitude details with a known frequency.

(c) Subtraction of the largest component:

Subtract the largest component from the initial signal.

$$x_{l=1}(t) = x(t) - x_1(t)$$

The outputs of the HVD Technique are shown in the figures (Fig. 4).

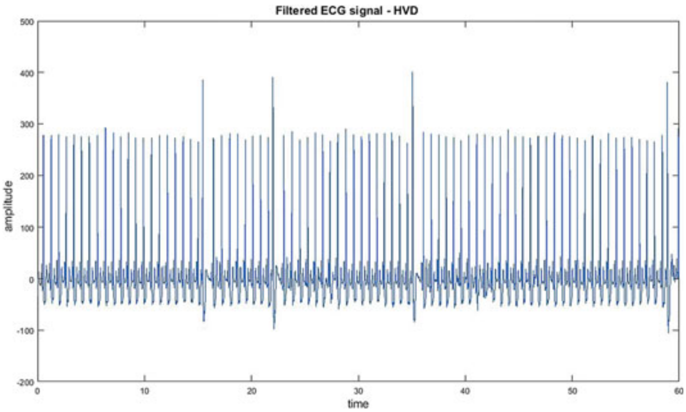

Fig. 4 HVD-filtered signal

2.1.4 Performance Metrics Comparisons

The three denoising techniques discussed above are applied on some of the recorded ECG signals available in the database, and their performances which are compared in terms of correlation criterion and SNR are tabulated.

PhysioNet database	DWT		EMD		HVD	
	Correlation (ϒ)	SNR	Correlation (ϒ)	SNR	Correlation (ϒ)	SNR
100	0.97	26.1	0.98637868	27.1229	0.99971302	45.9956
101	0.93	23.2	0.94212359	24.4681	0.99758573	38.5399
102	0.98	27.6	0.99739324	28.2829	0.99939312	38.7167
105	0.98	30.1	0.99110905	31.9607	0.99969329	44.2901
109	0.97	17.2	0.98532469	18.8084	0.99944116	36.879
111	0.97	26.4	0.98566024	27.1252	0.9991882	37.8521
112	0.94	20.1	0.95288089	21.8086	0.99483184	29.034
114	0.94	20.9	0.95746516	21.6429	0.99844693	27.316
115	0.97	27.6	0.98223207	28.4056	0.99895625	37.6982
116	0.86	25.2	0.87563436	26.8662	0.99259015	27.5232
118	0.94	23.6	0.95692183	24.966	0.99862837	29.7275
119	0.98	24.9	0.9912986	25.379	0.99839035	34.5063
121	0.66	17.1	0.67770319	18.1411	0.93164784	20.5073
233	0.98	21.5	0.99447502	22.515	0.99981577	39.4077
234	0.92	19.8	0.93065476	20.88	0.99969609	46.2976

From the above results, the overall performance of the HVD technique for removal of BW is significantly improved compared with the EMD technique [5] for the same BW signal. Thus, the proposed HVD technique is computationally efficient and better compared to EMD and DWT technique.

2.2 Signal Quality Assessment's

It is analyzed in two SQA methods (A) Features and rules based and (B) Filtering-based SQA method. This method consists of filtering stage, feature extraction, classification stage.

2.2.1 Features and Rules-Based Method

To determine the reliable heart rates by signal quality indices (SQIs). The signal quality was assessed by using features, rules and adaptive template matching [4].

2.2.2 Filtering and Threshold-Based Assessment Methods

Filters and Threshold-based Combined SQIs based on ECG quality estimator as shown in Fig. 5 is used for estimating the HR from the ECG signals [1].

2.2.3 Results and Discussion

To calculate the performance of quality assessments methods uses manual and automatic machine learning approaches to identify acceptable signals in terms of Sensitivity, Specificity, and Accuracy. Results show that features and rules-based method give 87.4% of Se%, 100% of specificity, and 90.2% of accuracy. Whereas, Filtering and threshold-based signal quality assessment methods had accuracy 94.2%, Sp of 100% and Se of 92.4%.

3 Conclusion

This paper presents analyzing of denoising filtering techniques. Overall performance is calculated in terms of correlation and SNR. In addition, this paper also presents ECG SQAs methods for acceptable ECG signal. Moreover, performance evaluations were only carried out for accurate identifications. For future extension, these methods are useful for real-time evaluation for telemetry healthcare monitoring applications.

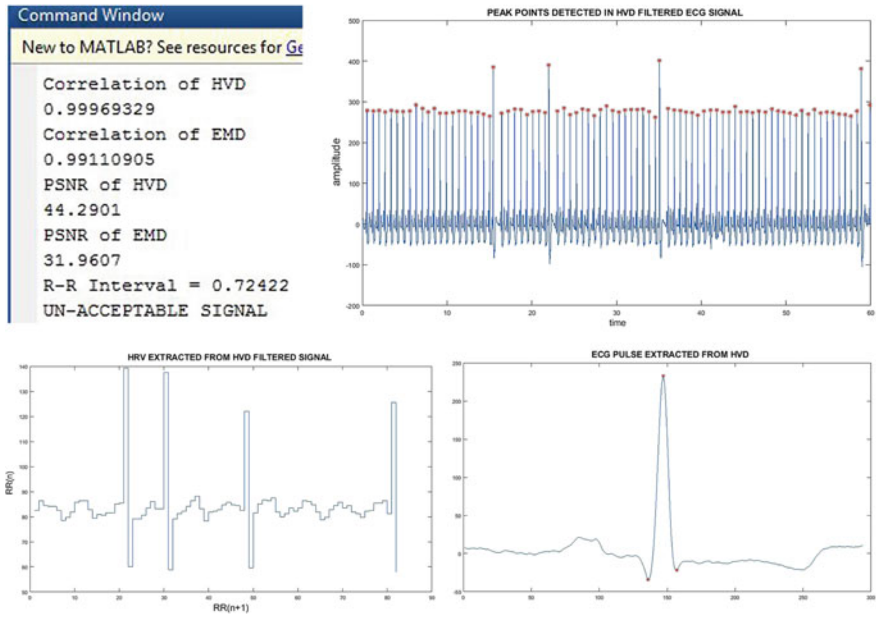

Fig. 5 Computation performance of SQA, peak detector, HRV, ECG pulse

References

1. Satija, U., Ramkumar, B., Manikandan, M.S.: Real-time signal quality-aware ecg telemetry system for iot-based healthcare monitoring. IEEE Internet Things J. **4**, 815–823 (2017)
2. Chukka, R.B., Kumar, C.S.: A novel architecture for IoT enabled ECG signal quality assessment using HVD based on PSoC System: a survey. J. Adv. Res. Dyn. Control Sys. **10**, 333–339 (2018)
3. Chukka, R.B., Kumar, C.S.: A novel architecture for the realisation of iot-enabled ECG signal quality assessment using wavelet decomposition for baseline wander removal. Def. S&T Tech. Bull. **11** (2018)
4. Christina, O., Timothy, B., Peter, C., David, C., David, V., Lionel, T.: Signal quality indices for the electrocardiogram and photoplethysmogram: derivation and applications to wireless monitoring. IEEE J. Biomed. Health Inform. **3**, 832–838 (2015)
5. Chukka, R.B., Kumar, C.S.: A novel architecture for the realisation of IoT-enabled ECG signal quality aware using empirical mode decomposition for telemetry healthcare system. IJET(UAE). Accepted for Oct 2018 Issue