Signal Enhancement of Wearable ECG Monitoring Sensors Based on Ensemble Empirical Mode Decomposition

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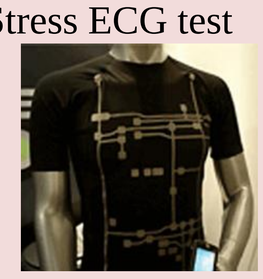
Abstract

The use of electrocardiogram (ECG) signals is an important standard for the diagnosis of heart diseases and other pathological phenomena. Wearable medical monitoring system is currently one of the most important individual-centered health-care systems. When the sensor is worn by patients during their normal activities, the ECG signal is always contaminated by different types of noise, especially the muscle and motion artifacts. This research proposes a novel ECG enhancement method, which is based on Ensemble Empirical Mode Decomposition, to eliminate the contact noise in the ECG signals. The performance of the proposed method is validated by using real data from the MIT-BIH database. Simulation results show that ECG signals from wearable monitoring sensors can be significantly enhanced by filtering out the contact noise while keeping all of the ECG features. The EEMD-based method exhibits obvious advantages over other similar ones in terms of de-noising.

Introduction

❖ Most wearable medical monitoring sensors are expected to be on patients who are walking or in activities.

❖ Stress ECG test

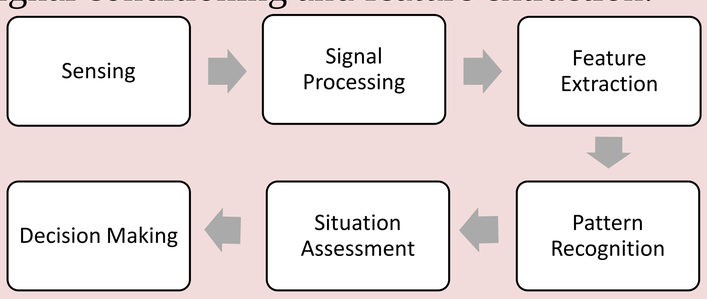


❖ Dominant noise: muscle and motion artifacts.

❖ Traditional signal enhancement methods are almost based on standard filter processing.

❖ Previous knowledge of the signals are demanded.

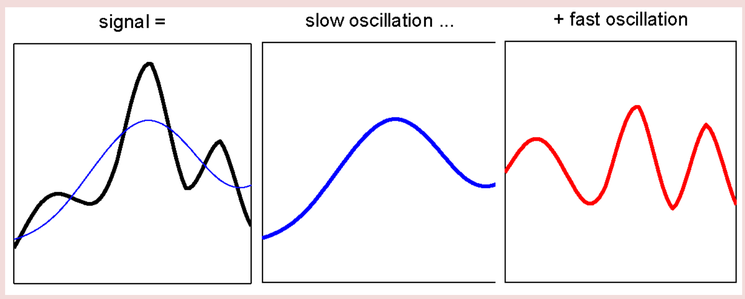
❖ New algorithms and technologies are needed to have the ability to perform both signal conditioning and feature extraction.



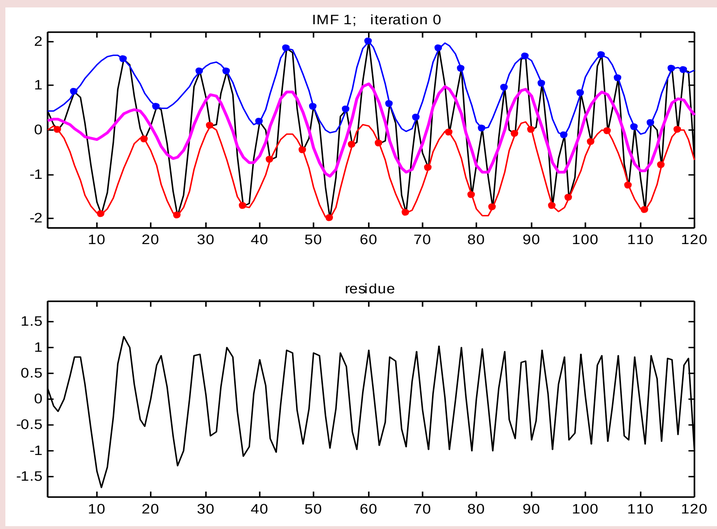
EMD & EEMD

❖ EMD is designed for representing non-stationary or nonlinear signals. All we need is the data itself. It is a technique to separate an arbitrarily given signal into a finite set of oscillatory components (named as Intrinsic Mode Functions, IMFs).

❖ Signal can be understood as a kind of fast oscillations superimposed to slow oscillations.



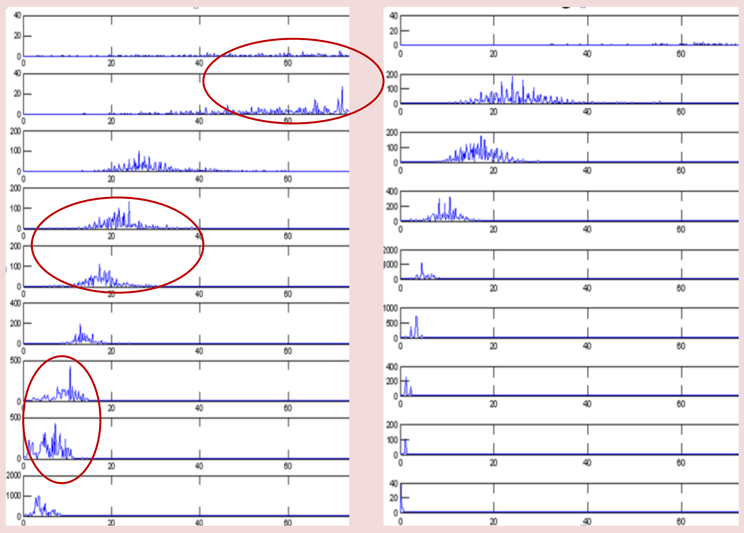
❖ The decomposition process used in EMD is called the sifting algorithm.



❖ The EEMD has the same decomposition process with EMD.

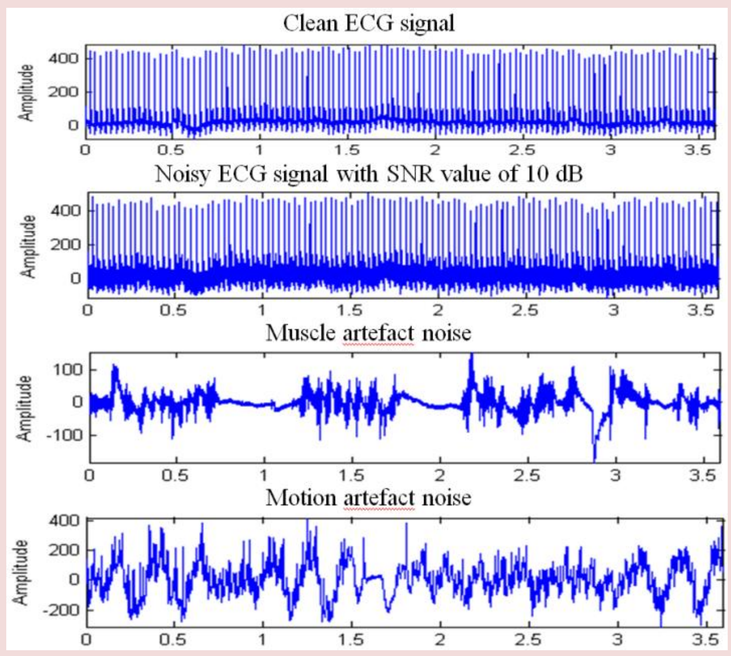
❖ The principle of EEMD is to add white noise into the original signal with several trials. The noise added is distributed with zero mean. The ensemble result is the original signal as more and more trials are added.

❖ The improved ensemble process of EEMD can reduce the mode-mixing problem that exists in the EMD algorithm.



Simulation Results

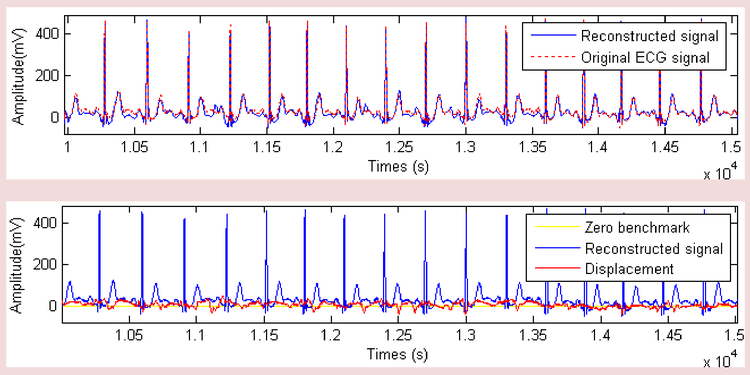
❖ Two types of noise are experimented: Gaussian White noise and contact noise.



❖The quantitative evaluation criteria used is signal-error-ratio (SER) and displacement.

❖ The following figures show the de-noising performance of reducing contact noise.

❖ The table presents the comparison of the de-noise results of EEMD and EMD.



Record	SNR = 6 dB		SNR = 10 dB		SNR = 14 dB	
	SER_{EEMD}	SER_{EMD}	SER_{EEMD}	SER_{EMD}	SER_{EEMD}	SER_{EMD}
100	11.57	11.40	15.53	13.95	17.39	16.75
103	11.38	9.85	14.65	12.90	18.57	15.70
105	12.70	9.62	15.96	11.94	18.68	14.54
119	15.49	11.45	20.68	14.71	22.02	17.29
213	9.15	8.87	15.24	11.89	17.99	14.74

Conclusions

❖ A novel EEMD-based method to remove noise from corrupted ECG signal is presented.

❖ The proposed algorithm delineates and separates the QRS complex effectively.

❖ Experiments on real ECG data corrupted by two types of noise are performed.

❖ The EEMD algorithm can be used to enhance other biomedical signals.