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Denoising ECG by Adaptive Filter with EMD

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Abstract— **Electrocardiogram (ECG) signal is an important physiological signal. In this paper, we first present a novel method based on EMD and adaptive filter for the removal of baseline wander (BW) and power line interference (PLI) in ECG signal. We then extend the method to the complex scenario where ECG is contaminated by four most common noises, PLI, BW, electrode motion artifact (EM) and muscle artifact (MA). Several efficient methods are proposed and proposed Parallel EMD adaptive filter structure yields the best SNR improvement on the MIT-BIH arrhythmia database.**

I. INTRODUCTION

Cardiovascular disease is one of the main threats to human life. Electrocardiogram (ECG) signal is important to diagnose cardiovascular disease. ECG signals are often corrupted by noises such as electrode motion artifact (EM), muscle artifact (MA), power line interference (PLI), and baseline wander (BW). We investigate denoising algorithm for ECG signal corrupted by four types of noise: BW, PLI, EM and MA. A novel algorithm to denoise PLI and BW using adaptive filter and EMD is presented. We extend the idea to all four types of noises and propose four denoising algorithms: Staged Direct Adaptive Filter (SDAF), Parallel Direct Adaptive Filter (PDAF), Staged EMD Adaptive Filter (SEAF) and Parallel EMD Adaptive Filter (PEAF).

II. METHODS

The basic idea of proposed methods is based on that EMD can decompose signals into stationary IMFs. Furthermore, different noise have their own spectrum, PLI is a single frequency noise, BW's frequency is concentrated on 0-3Hz, EM is a high frequency noise and MA occupies similar frequency range as ECG. Consequently, different noises can be represented by the sum of some IMFs. All ECG signals and noises are from MIT-BIH. We use the noise related signals as reference input of adaptive filter to estimate noise. The denoised combination of IMFs is obtained by subtracting the estimated noise. The denoised ECG is the sum of the denoised IMFs and other unused IMFs and residue. By comparing the performance in terms of SNR improvement ($SNRimp$), the best combination can be recognized. Results show that applying adaptive filter on IMF1 for PLI, sum of IMF5~IMF8 for BW, IMF3~IMF8 for EM and whole signal for MA yields the best result. First we consider the condition when both BW and PLI noises corrupts ECG. Adaptive filters are separately applied on IMF1 and sum of IMF5~8 to denoise PLI and BW, then sum denoised IMFs and unused IMF2-4 and residue to get denoised ECG. While dealing with all four noises, there are overlapped use of IMFs. The first method is parallel process. Corresponding adaptive filters are applied on IMF5~8 to denoise BW and IMF3~8 to denoise EM, then sum the denoised IMF5~8 and IMF3~8 up and subtract the overlapped IMFs. The second way is a staged process. We first deal with BW and get the denoised IMF5~8 (IMF58'). Afterwards, IMF3 and IMF4 are added on IMF58' to get adaptive filter's input to denoise EM. Setting the adaptive filter for MA at last performs better.

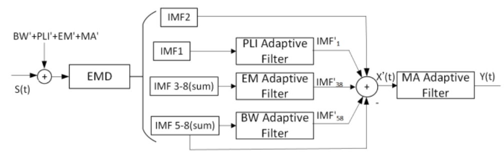

Figure 1. Proposed PEAF Structure to Denoise BW+PLI+EM+MA

III. RESULTS

We compare the results of the SNR$output$ under SNR$input$ = 10 (dB) in Fig. 2 with other SOA algorithms for BW and PLI corrupted ECG. Fig. 3 shows a comparison of the SNRimp using the proposed four methods at different SNR$input$ levels for ECG corrupted by all four noises and PEAF has the best performance.

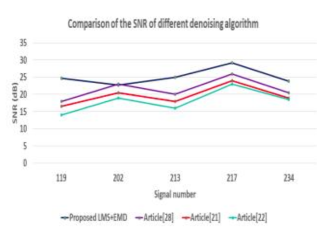

Figure 2. Compare with Article [1,2,3]

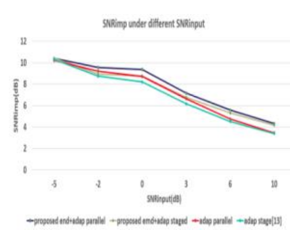

Figure 3.Compare four methods

IV. DISCUSSION & CONCLUSION

We proposed effective methods based on EMD and adaptive filter with better performance to denoise ECG corrupted by combined noise of BW and PLI and by BW, PLI, MA and EM simultaneously. Proposed PEAF has the best performance.

REFERENCES

[1] YIN Li, CHEN Fumin, ZHANG Qi, and CHEN Xin. ECG adaptive denoising method based on EEMD and improved threshold function. Journal of Xi'an Jiaotong University, 2020, 54:101–107.
[2] Zheng Minmin, Gao Xiaorong, and Xie Haihe. Research on an improved algorithm for wavelet denoising of ECG. Chinese Journal of Biomedical Engineering, 2017, 36(1):114.
[3] H. D. Hesar and M. Mohebbi. ECG denoising using marginalized particle extended Kalman filter with an automatic particle weighting strategy. IEEE Journal of Biomedical and Health Informatics, 2017, 21(3):635–644.

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