

Investigating wavelet based denoising for suppressing motion artifacts in ECG signals

Abstract—Wavelet based de-noising technique for suppressing motion artifact using modified limiting functions are investigated. Suppression of motion artifacts includes estimating limiting thresholds followed by limiting wavelet coefficients.

Index Terms—ECG, motion artifact, limiting.

1 INTRODUCTION

ECG is a measure of electrical activities of heart. These signals are obtained by placing surface electrodes at specific locations of the body. Various kinds of disturbances affect sensing and recording of these ECG signals. The electrode motion at skin-electrode interface causes changes in half-cell potential of the electrodes resulting in irregular baseline wander known as motion artifact. Wavelet based de-noising techniques are investigated to suppress these artifacts. Suppression of motion artifacts includes estimating limiting thresholds followed by limiting wavelet coefficients. Effect on motion artifact suppression by modifying limiting functions for limiting wavelet coefficients is the point of interest. Coefficient limiting using hard limiting function on detailed wavelet coefficients and different soft limiting functions with sinusoidal, piece-wise linear and parabolic transitions are investigated. The objective is to modify the limiting function for effective removal of motion artifacts.

2 ARTIFACTS IN ECG

The ECG signal gets corrupted by numerous artifacts. The origin and nature of these artifacts are important for long term monitoring applications. EMG noise and slow base line wandering are caused due to physiological reasons like muscular activity and respiration respectively. There are some artifacts which are due to non-physiological reasons, for example, 50 or 60Hz power line interference and motion

artifacts in ECG. The presence of the artifacts will make any diagnosis problematic.

2.1 EMG noise

Any muscular activity in the body produces a bio-potential signal which is also known as the electromyograph (EMG) signal. The spectrum of EMG is spread over the frequency range from 5 to 500Hz [1]. Since the EMG and ECG signals have partly overlapping spectra, the muscular activity may cause interference in the ECG signal. This type of noise is known as EMG noise. The patient is generally present in the rest condition during clinical testing and hence the origin of EMG noise has very low chance. Only few cycles of ECG signals are sufficient for short time monitoring purposes. However, for long term monitoring under ambulatory conditions the presence of high frequency EMG noise is problematic.

2.2 Motion artifact

The artifact caused due to motion of electrodes is known as motion artifact. Motion artifact arises due to imbalance in the electrical activity at the electrode-electrolyte and electrolyte-skin interfaces caused due to relative motion of electrodes or skin stretch or contract. The motion artifact has a significant overlap with the spectrum of the ECG signal in the frequency range 1-10Hz and hence it is very difficult to handle this type of artifact [1]. The motion artifact poses a major challenge in the long

term ambulatory cardiac monitoring using a wearable ECG equipment.

2.3 Base line wandering

Due to respiration, the change in volume of lung diaphragm changes the impedance of the path between the ECG electrodes. This variation in impedance results in a slowly changing potential difference for a constant current. A non-steady baseline can occur due to slow motion of the electrodes. This type of base line wandering is quite common in long term ECG monitoring. The slow wandering of the baseline can be eliminated by selecting a frequency value greater than 1Hz as the lower cutoff frequency of the ECG amplifier. However, the low frequency contents of the ECG signal (from 0.05 to 2Hz) are distorted due to this type of filtering [1].

2.4 Powerline interference

The power lines and the lead wires of the ECG recorder are coupled through capacitive paths. Depending on the amount of coupling, a 50/60Hz current flows in each of the lead wires. The currents follow the path from the corresponding lead wires through the body to the common ground. The powerline currents in both the leads would be the same assuming the distance between any two leads to be very small. However, due to the impedance difference (Z) in the paths taken through the body for both the currents, there will be an additional voltage difference (iZ) caused by the powerline. This voltage signal is further amplified along with the ECG signal by the difference amplifier which is referred as powerline interference. This type of interference appears as a 50 or 60Hz noise.

3 DENOISING

Baseline wandering and powerline interference can be reduced by careful design of ECG hardware. Motion artifact and EMG noise can be reduced by restricting the motion of the patient during signal recording, but this is not possible in ambulatory ECG recording. Hence, wavelet based de-noising techniques are investigated.

Most of the noise suppression techniques using wavelet thresholding are based on the assumption that the noise is always present and has low amplitude, and that the signal is present in specific time segments and has relatively high amplitude [13]. In ECG corrupted with non-stationary motion artifact, ECG signal is always present and the motion artifact occurs intermittently and it generally has high amplitude.

EMG noise is reduced by thresholding the wavelet coefficients using an improved thresholding function combining the features of hard and soft thresholding. Motion artifact is reduced by thresholding followed by limiting the wavelet coefficients [2]. Thresholds for both the denoising steps are estimated using the statistics of the noisy signal.

3.0.1 Thresholding

At scale i , the threshold Φ_i is an estimate of maximum value of wavelet coefficients of ECG signal. The threshold is sufficiently low to truncate the motion artifact and high enough preventing the loss of noise free ECG signal. At each scale i , the maximum absolute values of coefficients are used to calculate the mean μ_i and the standard deviation σ_i . The limiting threshold at scale i is calculated as $\Phi_i = \mu_i - \eta\sigma_i$, where η is the motion artifact control parameter.

3.0.2 Limiting

Limiting is the operation carried out on wavelet coefficients $D_i(n)$, using threshold ϕ_i . The following limiting functions are investigated in detail.

- Hard limiting
- Soft limiting
 - piece-wise linear
 - sinusoidal transition
 - parabolic transition

4 RESULTS

5 CONCLUSION

The conclusion goes here.

REFERENCES

- [1] S. Chaudhuri, T. D. Pawar, and S. Duttagupta, *Ambulation Analysis in Wearable ECG*. New York: Springer, 2009.
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