Efficient Linear-phase High-pass Filter for ECG

Richard E Gregg, Junmo An, Ben Bailey

Philips Healthcare
Cambridge, MA, USA

Background: Simple infinite impulse response (IIR) high-pass filters for ECG cause ST-segment distortion due to the overshoot in the impulse response unless the cutoff frequency is very low. Linear-phase filters solve the ST distortion problem. We aim to characterize and compare a multi-boxcar high-pass filter which approximates a windowed finite impulse response (FIR) filter design.

Methods: Four 0.5 Hz linear-phase high-pass filters were compared. The reference high pass-filter was a single pole IIR filter with a corner frequency of 0.322 run in the forward and backward directions for an overall 0.5 Hz cutoff frequency (Forward-Backward). The other filters were a 0.5 Hz boxcar (Boxcar), a weighted average of 9 boxcar filters to approximate a Blackman window (Multi-Boxcar), and a moving window median (Median). The filters were compared by average power spectrum on a 12-lead ECG database of prehospital ECGs containing significant baseline wander (n=5,368).

Results: The average power spectrum for the boxcar high-pass filters shows higher levels of low frequency attenuation. The multi-boxcar filter shows a lower passband ripple than the boxcar. The maximum (mean) absolute deviation from the raw signal power spectrum in the 1.0 to 10 Hz range was 0.86 (0.09), 1.6 (0.34), 0.27 (0.05) and 0.19 (0.04) dB for the Forward-Backward, Boxcar, Multi-Boxcar and Median filters, respectively.

Conclusion: A multi-boxcar high-pass filter improves the passband ripple compared to a simple boxcar high-pass while retaining an efficient design and matching the frequency response of the linear-phase IIR filter. The trade-off is a delay on the order of one second.