Multichannel ECG Filtering: Source Consistency Filtering, Eigenfiltering and Traditional Methods

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Mortara introduced the spatial consistency filter (SCF) in 1992. The SCF exploits the redundant spatial information of the cardiac dipole in 12 lead ECG to reduce noise while maintaining QRS amplitude and shape. Since its initial publication, the algorithm has not been systematically evaluated in the literature. In this study, we assessed the performance of the SCF in a noisy environment.

The SCF was conceived for the higher frequency noise in applications such as stress ECG. For this reason, we tested the algorithm on a synthetic ECG database with the addition of higher frequency noise. We synthesized 40, 5-minutes long ECG records using the simulator proposed by Petrėnas *et al*. We then added bursts of noise in the electromyographic frequency band, 5 to 70 Hz, uncorrelated between leads. The SNR ratio of each burst of noise varied randomly from -10 to -1 dB.

We measured the mean absolute filtering error (MAE) for the whole ECG record and around the QRS complex. We also measured the QRS detection performance before and after filter application. We compared the results with the conventional lowpass FIR filter (LPF, 25 Hz and 40 Hz) and a spatiotemporal eigenfilter based on singular value decomposition (SVD). The singular values and singular vectors are estimated on an initial, noise-free part of the ECG recording. The signals of the whole recording are decomposed using those initial singular vectors and then reconstructed with a subset of them.

Our results indicate that the SCF can afford a QRS complex distortion lower than that of a 40 Hz lowpass filter while still maintaining a high noise rejection. The QRS detection accuracy on the filtered ECG was comparable for all methods except for the SVD filter, which allowed a superior detection performance score in all the records.

Algorithm	Global error MAE, µV	QRS error MAE, µV	QRS detection, F1 Mean (min – max)
25 Hz LPF	44.42	9.57	0.973 (0.762 – 1.000)
40 Hz LPF	70.16	8.94	0.969 (0.749 – 1.000)
SVD filter	**37.39**	8.92	**0.997 (0.989 – 1.000)**
SCF	53.11	**8.23**	0.970 (0.756 – 1.000)