An Extension of Quadratic variation regularization for simultaneous baselinewander and powerline interference removal from ECG

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Objective: Two of the most common noises that overlap with the frequency band of electrocardiogram (ECG) signals are powerline interference (PLI) and baseline wonder (BW). The removal of these two noises remains a challenging task. Quadratic variation (QV) regularization is a recent method for BW removal but cannot be used for PLI cancellation. To overcome this limitation, an extension of QV regularization which can simultaneously deal with BW and PLI tracking and removal is presented.

Methods: PLI and BW are respectively modeled by a sinusoidal and a polynomial function. The difference equation of the sinusoidal function and the p-th order derivative of the polynomial function are then used as constrains in the optimization problem:

$$\hat{x}_k, \hat{z}_k = \underset{x_j, x_j}{\operatorname{argmin}} \sum_{j=1}^{L} \Big(y_j - x_j - z_j \Big)^2 + \lambda_1 \sum_{j=1}^{L} \Big(x_j - \gamma x_{j-1} + x_{j-2} \Big)^2 + \lambda_2 \sum_{j=1}^{L} \left(z_j + \sum_{i=1}^{p} \alpha_i z_{j-i} \right)^2 , \; \gamma = 2\cos(2\pi f_0), \; \alpha_i = (-1)^i \binom{p}{i}$$

where x_j and z_j are the PLI and BW, respectively, $f_0 = 50/60$ Hz, λ_1 and λ_2 are the regularization factors. The computational complexity of the algorithm is linear which makes it suitable for real-time applications.

Results: We tested the method over data from the PhysioNet PTB database. Simulation results confirm the effectiveness of the approach and highlight its ability to simultaneously track and remove the PLI and BW. QV regularization is a special case of the proposed method when we set the regularization factor for the PLI term to zero ($\lambda_1 = 0$) and $p = 1$.

Conclusion: An extension of QV regularization was proposed which can be used not only for BW tracking but also for PLI tracking and removal.

Significance: PLI and BW removal is an essential initial step in preprocessing of the bio-electrical signals (*e.g.*, ECG, PPG and EEG). The results of this paper improve the QV regularization performance for simultaneous removal of PLI and BW without increasing the computation load.