A New DDE Smoothing Filter for ECG Signal Denoising

Arman Kheirati Roonizi[1,2], Roberto Sassi[2]

[1]Department of Computer Science, Fasa University, Daneshjou blvd, 74616-86131 Fasa, Iran
[2]Dipartimento di Informatica, Università degli Studi di Milano, Via Celoria 18, 20131 Milano, Italy

Objective: Signal filtering is a challenging problem arising in many applications such as Electrocardiogram (ECG) signal processing. Among the techniques that are used for signal denoising, quadratic variation (QV) regularization and smoothness priors have received significant attention during the past. In this paper, we propose a new approach to smoothing filter design, which is based on a delay differential equation (DDE).

Methods: A DDE is used in the regularization term of the optimization algorithm. The method depends on the regularization parameter and the delay, where the former is related to the cutoff frequency and the latter is set by user.

Results: The DDE smoothing filter was analyzed in the frequency domain. It was shown that smoothness priors and QV regularization are special cases of the DDE smoothing filter when the delay tends to infinity. As an application, the proposed smoothing filter was used for ECG signal denoising over data from the PhysioNet PTB database. The results confirm that the proposed smoothing filter outperforms QV regularization for ECG BW removal.

Conclusion: A new smoothing filter was proposed in this paper which improves signal preprocessing without increasing the computation load.

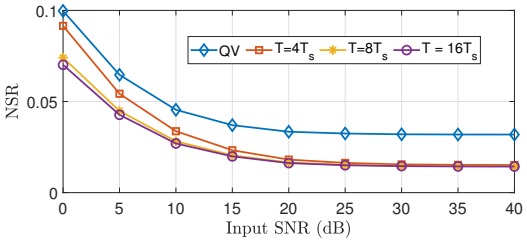

Figure 1. Mean values of NSR (defined as $\sqrt{\int (x(t) - \hat{x}(t))^2 / \int x^2(t)dt}$, where $x(t)$ and $\hat{x}(t)$ are respectively the original and estimated signal) for ECG BW removal by QV regularization and the proposed filter with different values of delay T, as a function of the power of the BW corrupting the ECG signal. T_s is the sampling period.