Morphology-Preserving Denoising of Exercise ECG Using Adaptive-Filter Supervision and a 1D CNN Autoencoder

Abdulhamed M. Jasim, Noor Qaqos, Shamsu Idris Abdullahi, Ekenedirichukwu N. Obianom, Fan Feng, G Andre Ng, Xin Li

University of Leicester, Leicester
England, United Kingdom

Recording electrocardiogram (ECG) signals during treadmill exercise is strongly affected by electrode motion and muscle artefacts, and in many scenarios, reference ECG signals are unavailable, making it difficult for supervised algorithms to train. To address this issue, this approach proposes a hybrid framework that integrates traditional DSP with deep learning techniques for ECG denoising and preserving the signal morphology. First, the autoencoder uses the noisy exercise data as input signals, while the denoised signals are used as targets. The target signals are generated using our previously published hybrid adaptive filtering approach (Jasim *et al*., 2025). After a one-time training of the 1D CNN autoencoder, new ECG recordings can be denoised by a single forward pass through the network, avoiding repeated adaptive filtering. The proposed approach was evaluated using a private exercise ECG dataset from 48 subjects sampled at 1000 Hz. This database is collection of patients suffering from ischaemic cardiomyopathy, who were undergoing an implantable cardioverter defibrillator (ICD) implant and treadmill exercise testing. ECG recordings were segmented into fixed 5s windows and split subject-wise into training, validation, and test sets (38/4/6 subjects) to avoid data leakage. Regarding the test set, the proposed model achieved a mean normalized RMSE of 0.1206 ± 0.0566 and a mean normalized PRD of 14.90% ± 9.08%. In terms of signal quality, the average SNR increased from 4.22 ± 4.39 dB to 14.40 ± 3.74 dB, corresponding to an average SNR improvement of 10.18 ± 3.89 dB. These results show that the proposed approach rapidly and effectively learns ECG features and preserves the signal morphology, supporting effective noise removal for exercise ECG in the absence of true ground truth.

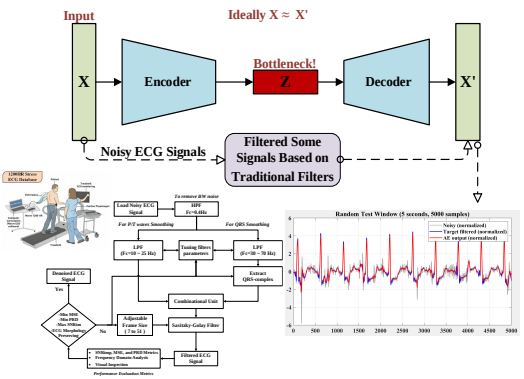

Fig. 1. Flowchart of the Proposed ECG Denoising Method.