A Generative Methodology for PPG to ECG Reconstruction Based on Dual-Critic Approach

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Aims: Cardiovascular diseases (CVDs) are the leading cause of mortality worldwide. Despite the wide use of conventional electrocardiogram (ECG) in CVD detection, they often seem inconvenient for long-term continuous monitoring. Wearable ECG devices are very useful in this scenario, especially photoplethysmography (PPG) based ones, for advantages such as unobtrusive, lead-less, and patch-less monitoring. This study proposes a novel architecture for PPG to ECG reconstruction that uses a Dual-Critic Generative Adversarial Network (GAN) utilizing Wasserstein-Loss and Discrete Wavelet Transform (DWT) in the frequency domain as a critic.

Methods: We used raw ECG data with lead II configuration and PPG data from the publicly available BIDMC dataset, which consists of data taken from 53 adults. We then preprocessed the data and segmented it into 4-second windows. We used a single generator to reduce model complexity. For the unification of ECG features in generated data, we used a dual discriminator, one working in time and the other in the frequency domain. The overflow of the proposed model is shown in Fig. 1.

Results: Performance evaluation was done by calculating the metrics such as root mean squared error (RMSE), mean absolute error (MAE) for heart rate (HR), and percentage root mean square difference (PRD) between original and generated ECG signals. A quantitative comparison with some earlier studies through these metrics is shown in Table 1.

Conclusion: The results of this work are significantly comparable to other existing works. Incorporating LSTM layers, Wasserstein loss, gradient penalty, and dual discriminators as critics of the generator helps eliminate the vanishing gradient problem and reconstruct accurate ECG from PPG input, resembling the ground truth.

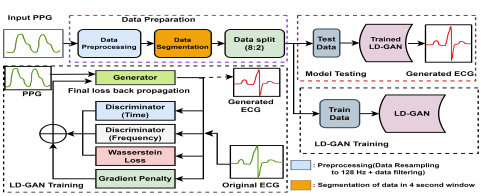

Figure 1: The proposed model process flow.

Methods	RMSE	MAE (HR)	PRD
CGAN+CNN	0.668	–	–
BiLSTM-CNN GAN	0.215	–	51.799
CardioGAN(Wasserstein loss)	0.157	–	38.566
Proposed method	**0.134**	**3.75**	**6.064**

Table 1: Metric Comparison among various models.