Generating Precordial-lead Electrocardiogram from smartwatch

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Abstract

The market for smartwatches is growing as wearable devices are proving to be effective for monitoring fitness and health. The acquisition of electrocardiogram (ECG) data with a smartwatch is limited because only a single lead can be obtained using two electrodes, which restricts the detection of heart disease. To address this limitation, this study aims to compare the chest lead ECG data generated by generative adversarial networks (GAN) with the chest lead data obtained using a standard 12-lead ECG device. This study collected ECG data from both Galaxy watch4 classic and a standard 12-Lead ECG device. Single lead ECG data was obtained from the smartwatches. A total of 10 healthy volunteers participated in the experiment, and 100 datasets were collected. The performance of the smartwatch-generated data was evaluated using Fréchet distance (FD) score and mean squared error (MSE) as evaluation methods. The study found that the mean FD score was 15.4591 and the mean MSE score was 0.0937. These scores indicate that the generated ECG signal from the smartwatch had a high level of similarity to the standard 12-Lead ECG signal. Specifically, the MSE and FD scores were low, indicating that there was a high degree of similarity between the two signals. The study demonstrated that the need to change the placement of the smartwatch to obtain different leads can be eliminated by generating chest lead ECG signals using a single smartwatch. This approach provides a way to overcome data restrictions associated with obtaining only a single lead ECG signal from smartwatches. Therefore, the generated ECG signals can offer a practical and convenient alternative for monitoring heart health using smartwatches.

1. Introduction

Various methods can be used to obtain electrocardiograms (ECGs), with Holter monitoring and the standard 12-lead measurement being among the most commonly used [1]. The standard 12-lead ECG involves leads divided into two groups: limb leads and precordial leads. Each group provides a different perspective on measuring the heart's electrical activity. The limb leads, which include leads I, II, III, aVR, aVL, and aVF, utilize Einthoven's triangle to observe the heart's electrical activity from different angles. They are instrumental in detecting conduction abnormalities, ventricular hypertrophy, and other cardiac conditions. In contrast, the precordial leads (V1, V2, V3, V4, V5, and V6) are based on Wilson's central terminal, a virtual reference point in the center of the chest. These leads are placed on the chest wall to record the heart's electrical activity in a horizontal plane. Precordial leads are particularly useful in evaluating the overall heart function and diagnosing conditions such as heart failure, myocardial infarction, and ventricular arrhythmias. The combined information from these leads is invaluable in diagnosing heart disease as they precisely identify the electrical activity pattern of the heart.

In recent studies, smartwatch ECG has been extensively used, with some demonstrating high accuracy in diagnosing atrial fibrillation using data acquired from these devices [2]. However, one limitation of smartwatches is that they typically measure only a single-lead ECG, which can restrict their ability to diagnose certain heart diseases comprehensively. To address this limitation, additional leads are needed to enable the diagnosis of heart conditions related to both limb and precordial leads, rather than relying solely on a single lead. To overcome this limitation, researchers have widely proposed ECG lead conversion methods [3,4]. Since smartwatches have only two electrodes, they cannot simultaneously measure ECG data from multiple leads. To work around this, researchers have explored various approaches to measure multiple leads using smartwatches. In conclusion, while smartwatches show promise in diagnosing atrial fibrillation and other heart conditions, leveraging additional leads through ECG lead conversion methods can enhance their diagnostic capabilities for a more comprehensive assessment of heart diseases.

2. Methods

This study collected ECG data from both Galaxy watch4 classic and a standard 12-Lead ECG device. Single

lead ECG data was obtained from the smartwatches. A total of 10 healthy volunteers participated in the experiment, and 100 datasets were collected.

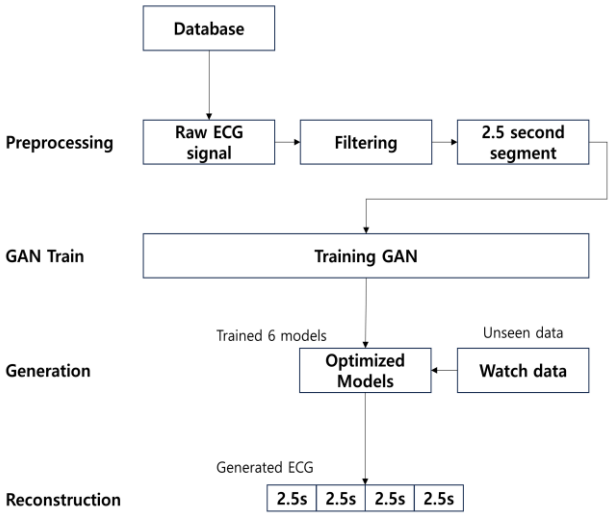

Figure 1. Overall structure of proposed method.

2.1. Data Acquisition and Preprocessing

This study involved the simultaneous collection of data from a standard 12-lead ECG device and a smartwatch in 10 healthy volunteers. The smartwatch allowed data extraction through connected mobile phones in CSV format, capturing 10-second segments. The standard 12-lead ECG data was stored in XML format and extracted through a USB connection, also providing 10-second recordings. The sampling rate was 500 Hz for the Galaxy Watch. Data were synchronized, and noise was filtered using a Butterworth bandpass filter 0.5–50 Hz.

2.2. Model description

In this study, a GAN-based deep-learning model was utilized to generate precordial leads ECG data from single-lead ECG recordings obtained through a smartwatch. The GAN model consists of a generator and discriminator, trained in a feedback loop to create synthetic data resembling known data distributions. The training data were sourced from Asan Medical Center records and preprocessed before training. The GAN framework generated data, which was then reconstructed by combining four 2.5-second segments into a single 10-second data segment. The generator model used skip connections and had seven convolutional layers for the encoder and seven up-convolutional layers for the decoder. The discriminator comprised five convolutional layers with batch normalization and a leaky ReLU activation. A total of 6 models were trained, one for each lead, with optimized hyperparameters and a batch size of 32. The proposed GAN model successfully generated precordial leads ECG data from the single-lead recordings obtained from the smartwatch.

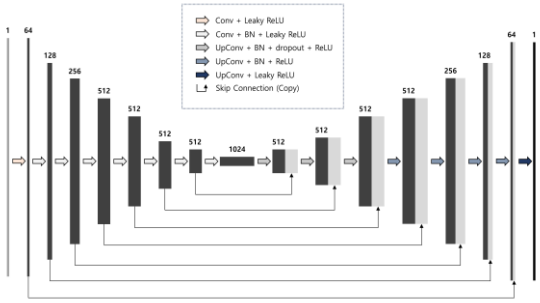

Figure 2. U-net generator architecture.

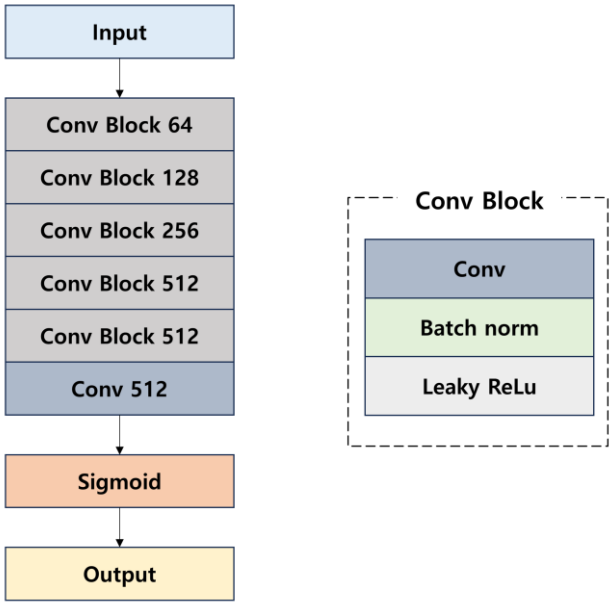

Figure 3. Discriminator architecture.

2.3. Model evaluation

MSE was used to measure the average difference between the two signals, which can be used to validate the amplitude difference between them. A lower MSE value indicates a smaller difference between the two signals, suggesting a higher degree of similarity between the two signals. MSE is expressed as in the following

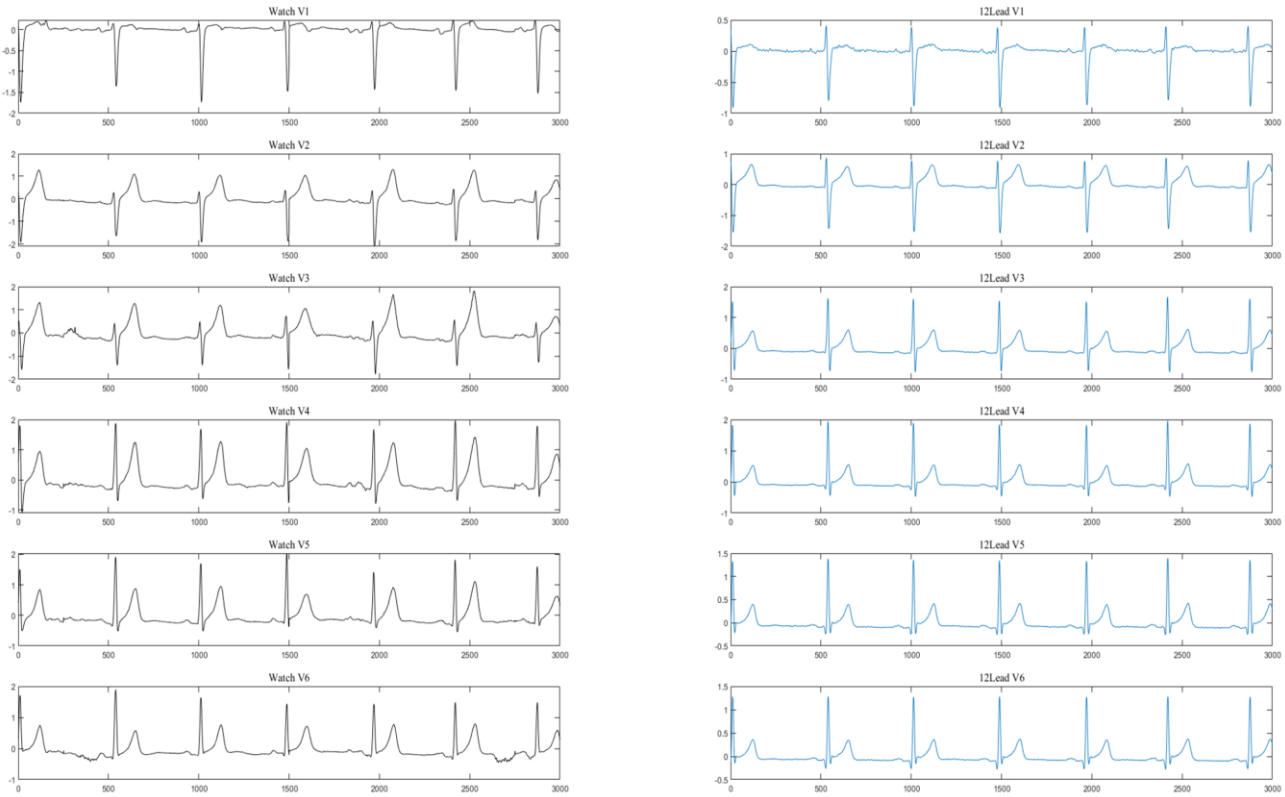

Figure 4. Left side of the signal with black lines are generated precordial lead ECGs and right side of the figure with blue lines are reference precordial lead ECGs.

equation:

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(X_i - Y_i)^2 \quad (1)$$

The FD score was used to assess the similarities between the generated data and reference data curves, and can validate the synchronization of the generated signal and the reference signal. FD score is expressed as in the following equation:

$$\text{FD}(r,g) = \|\mu_r - \mu_g\| + Tr(\sum r + \sum g - 2(\sum r \sum g)^{\frac{1}{2}}) \quad (2)$$

	Experiment	
	FD	MSE
V1	4.6941	0.0395
V2	19.3915	0.1172
V3	20.6850	0.1415
V4	21.5723	0.1300
V5	15.4699	0.0863
V6	10.9421	0.0482

Table 1. FD score and MSE score results

3. Results

Figure 4 illustrates the generated precordial leads from smartwatch single lead data, with the left side displaying generated signals for the precordial leads, and the right side showing the real ECG signals. The FD score and presented in Table1. The mean FD score and MSE score for were 15.4591 and 0.093, respectively.

4. Discussion

This study emphasizes the development of a more accurate and practical precordial leads ECG signal generation method using only lead I data from a smartwatch. This approach eliminates the need for handling asynchronous data and complex integration techniques, leading to higher accuracy and simplicity. Smartwatch precordial leads ECG generation has significant implications, reducing the need for traditional monitoring equipment and providing continuous and

convenient heart health monitoring. It improves accuracy, detects abnormalities, and allows for prompt action in emergencies. Challenges include ensuring data privacy and security. Overall, this technology has the potential to revolutionize wearable health monitoring and enhance patient care.

5. Conclusion

Smartwatch precordial lead ECG generation has transformative potential in wearable health monitoring, offering convenient and accessible heart health tracking. The generated ECG signals closely match reference signals, enabling clinical diagnosis. This technology enhances ECG accuracy, aids in early heart condition detection, and reduces reliance on traditional monitoring equipment, potentially lowering healthcare costs. Continuous monitoring via smartwatches improves accessibility and portability, further enhancing heart health monitoring.

Acknowledgments

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