Internet of Things-based Remote ECG Reconstruction System

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IoT 기반 무선 심전도 신호 복원 시스템

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Abstract

The organ responsible for circulating blood throughout the body via a network of vessels is the human heart. To diagnose different heart diseases and abnormalities, an electrocardiogram (ECG) captures electrical pulses generated by the heart's muscle activity, which can be detected through the skin. However, when the ECG data is transmitted wirelessly to a physician for remote analysis, it can be distorted by noise in the channel. To ensure the accuracy of the data, it is necessary to remove this noise through filtering techniques. An Internet of Things (IoT) based model has been developed to address this issue, using filters such as the moving average filter, the savitzky golay filter, and a smoothing filter to process.

Ⅰ. Introduction

An electrocardiogram (ECG) is a test that records the electrical activity of the heart. The word "electro" refers to electricity, "cardio" refers to the heart, and "gram" means record. The heart is a vital organ located in the chest on the left side that plays a central role in the circulatory system by repeatedly contracting and relaxing to pump oxygen-rich blood through the body via the arteries and return deoxygenated blood back to the lungs via the veins. An ECG is used to evaluate the function of the heart's chambers by producing a graphical representation of the heart's electrical activity.

A visual representation of a normal heart rhythm, shown in Figure 1, displays three distinct waves known as the P wave, QRS complex, and T wave. These electrical impulses are produced by the four chambers of the heart as it contracts and relaxes. A normal heart rate is typically between 60 and 90 beats per minute [1]. However, variations in the position, presence, absence, and duration of these waves can indicate potential issues with heart function. One such condition is ST-segment elevation myocardial infarction (STEMI), a severe heart attack that can be fatal if not treated promptly. With every 30 minutes of delay in treatment, the risk of mortality increases by 7.5%. To address this challenge, the FastECG app allows wireless transmission to reduce mortality risk. The ECG ECG data is sent to cardiologists before the patient reaches the hospital [2].

During an ECG recording, noise can contaminate the signal, producing false information for the physician. This contamination may occur due to a loose connection of the ECG electrodes to the patient's skin, interference from AC power lines, or patient movement during the recording.

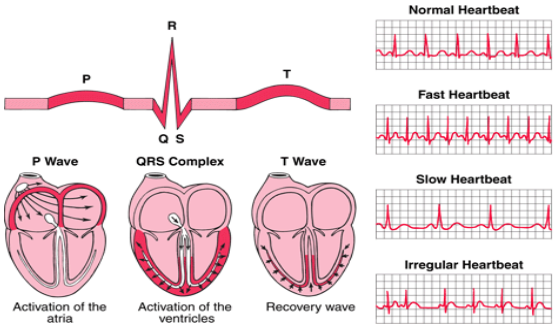

Figure 1. One cycle of a normal heartbeat.

This research aims to propose a system that offers remote ECG monitoring services to individuals with cardiovascular conditions. The system ensures the accurate and efficient transmission of ECG data from the patient's home to the physician, with minimal loss of information, to ensure accurate diagnosis and treatment as in

Figure 2.

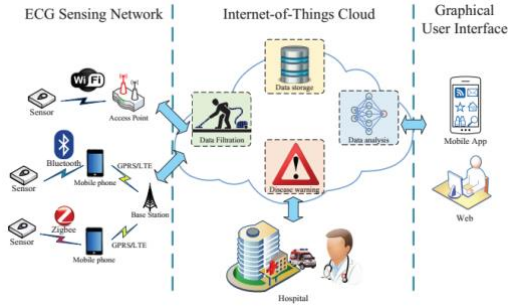

Figure 2. IoT-based ECG signal transmission.

This process is based on the Internet of Things (IoT) environment. The sensors collect and transmit the ECG data wirelessly through a single channel and multiple channels. Similarly, the collected noisy ECG data is then passed through the individual and multiple filters, and their results are averaged for better reconstruction results.

Ⅱ. Method and Results

In the first case, a single channel uses a single filter to check noise filtration. The block diagram of the model is shown in Figure 3.

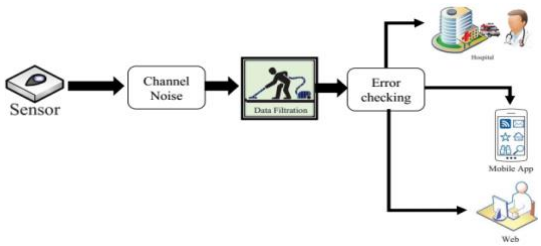

Figure 3. Single channel and filter for ECG recovery

The original ECG signal passes through a noisy channel in the first step. The second step applies three filters: savitzky golay filter, moving average filter, and smoothing filter. In step three, error ratios RMSE, MSE, and PRD were checked. In the second scenario, data from a single sensor is collected from patients with cardiovascular disease and transmitted via a wireless channel containing additive white Gaussian noise. The noisy ECG signal is passed through three filters for denoising.

In the third part, patient ECG data is collected using three sensors instead of one sensor, as shown in Figure 4. Then these sensor data are transmitted by three different channels containing various AWGN noises. Finally, the channel results are averaged. After averaging, this combined data is further passed through three filters for noise reduction. Finally, the output of these filters is again averaged.

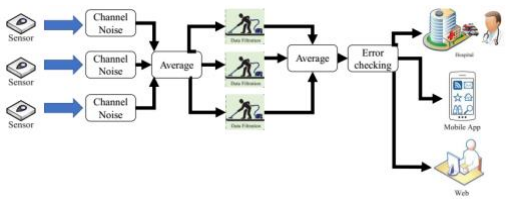

Figure 4. Multiple channels, multiple filters.

The simulation collects ECG signal data from the MIT-BIH Arrhythmia database. Processing is done in a MATLAB environment. Three filters (savitzky golay filter, moving average filter, and smoothing filter) are applied to ECG data for noise reduction. ECG data is transmitted through wireless channels containing various AWGN noise, and filters error are simulated concerning SNR to observe their best window sizes. Figure 5 shows the MSE and RMSE results of the different filtering schemes.

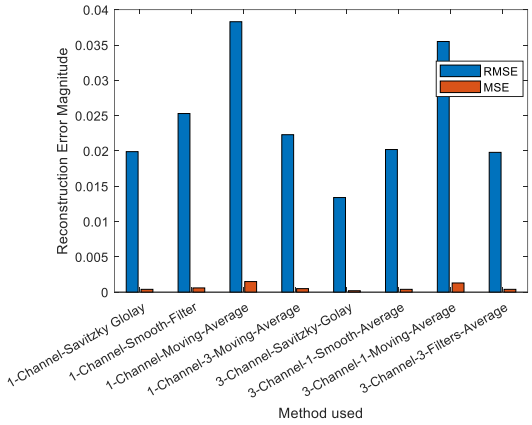

Figure 5. ECG reconstruction error.

Ⅲ. Conclusion

The problem in tele-health care is the effect of noise signals on the transmitted signal. In the existing system, if a single ECG signal is transmitted, there is a higher probability of noise contamination. This paper proposes an IoT-based system that collects data from three sensors and disseminates those signals using three different channels.

ACKNOWLEDGMENT

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