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PPG SIGNAL QUALITY ASSESSMENT AND ARTIFACT RE- MOVAL FRAMEWORK

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Abstract

This research proposes a framework for PPG signal quality assessment and artifact re- moval using signal preprocessing, statistical feature extraction, and machine learning tech- niques. A composite Signal Quality Index (SQI) is constructed using statistical features such as kurtosis, entropy, and skewness. These features allow automatic evaluation of signal reliability and enable classification of clean and corrupted signals.

Experiments were conducted using the MIMIC-III waveform dataset. Results demon- strate that the proposed framework effectively detects noisy signal segments and improves overall signal quality. The proposed approach enhances the reliability of wearable health- care monitoring systems and enables more accurate physiological measurements. Photo- plethysmography (PPG) is a non-invasive optical sensing technique widely used to monitor physiological parameters such as heart rate, oxygen saturation, and blood pressure. Due to its simplicity and low cost, PPG sensors are commonly integrated into wearable healthcare devices including smartwatches and fitness trackers. However, PPG signals are highly sensi- tive to noise, motion artifacts, and environmental disturbances. These disturbances distort the waveform and reduce the reliability of physiological measurements.

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Keywords: *Photoplethysmography; Signal Quality Index; Artifact Removal; Machine Learn- ing; Wearable Healthcare.*

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1. Introduction

Photoplethysmography (PPG) is a widely used optical technique for monitoring cardiovas- cular activity in a non-invasive manner. The technique works by emitting light into the skin and measuring variations in light absorption caused by changes in blood volume within microvascular tissues. Because PPG sensors are compact and affordable, they are widely integrated into wearable devices such as smartwatches and fitness bands [1].

PPG signals provide valuable information about cardiovascular health. Important phys- iological parameters such as heart rate, oxygen saturation, respiration rate, and heart rate variability can be extracted from the waveform [2]. More recently, researchers have also explored the possibility of estimating blood pressure and blood glucose levels using PPG sig- nals [3].

Despite these advantages, PPG signals are highly sensitive to disturbances. Motion arti- facts, environmental light interference, and sensor contact variations can significantly distort the waveform. These distortions often reduce the reliability of physiological measurements and limit the effectiveness of wearable monitoring systems [4]. Therefore, improving signal quality is essential for accurate health monitoring.

This work proposes a signal quality assessment framework that combines signal prepro- cessing techniques with statistical feature extraction and machine learning classification to detect corrupted PPG signals and improve signal reliability.

2. Background and Related Work

Several studies have investigated methods for improving the reliability of PPG signals. Motion artifacts remain one of the most significant challenges because their frequency components often overlap with the physiological signal [6]. Researchers have proposed various filtering and adaptive techniques to address this issue.

Signal quality assessment methods have also been widely studied. Previous work introduced signal quality indices based on statistical and morphological features to identify corrupted signal segments [1]. Machine learning algorithms have further improved artifact detection by learning patterns from signal data [4].

Reliable signal quality assessment is therefore essential for improving the performance of wearable healthcare systems.

3. Methodology

The proposed framework consists of four main stages: signal acquisition, signal preprocessing, feature extraction, and machine learning classification.

3.1 Signal Acquisition

The dataset used in this research is obtained from the MIMIC-III waveform database. This dataset contains physiological recordings collected from intensive care unit patients. The PPG signals in the dataset are sampled at approximately 125 Hz [5].

3.2 Signal Preprocessing

Raw PPG signals contain several forms of noise. Baseline wander is removed using high- pass filtering and detrending techniques. Wavelet-based denoising is applied to eliminate high-frequency noise while preserving the physiological waveform characteristics.

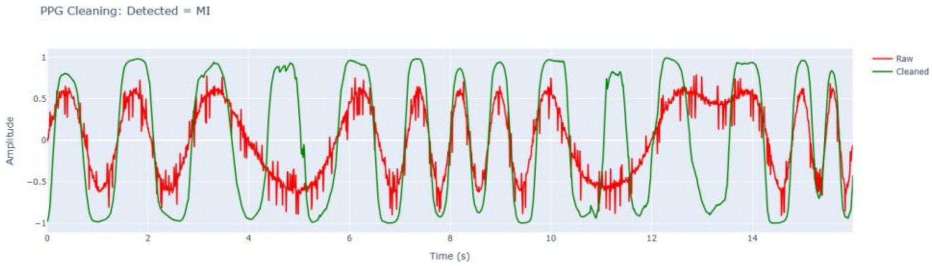

Figure 1: Raw PPG signal obtained from the dataset

3.3 Feature Extraction

Statistical features are extracted from PPG signal segments to characterize signal quality.
Kurtosis measures the sharpness of the signal distribution:

$$K = \frac{E[(X-\mu)^4]}{\sigma 4} \tag{1}$$

Entropy measures randomness within the signal:

$$H(X) = -\sum p(x)\log_2(p(x)) \tag{2}$$

Skewness measures asymmetry in the signal distribution.

3.4 Machine Learning Classification

A Random Forest classifier is used to classify signal segments into clean and corrupted cat- egories. Random Forest combines multiple decision trees to improve classification accuracy and reduce overfitting.

4. Results and Discussion

The proposed framework was evaluated using PPG signals obtained from the MIMIC-III dataset.
The results indicate that the proposed framework effectively detects corrupted signals and improves overall signal quality.

Table 1: Extracted Signal Features

Feature	Description	Value
Kurtosis	Signal peakedness	-1.4067
Entropy	Signal randomness	3.4800
Skewness	Signal asymmetry	-0.0894

Table 2: Classification Performance

Class	Precision	Recall	F1-score
MI	0.96	0.93	0.95
Normal	0.94	0.96	0.95
		Accuracy	0.95

5. Conclusion

This paper presented a framework for evaluating PPG signal quality and removing artifacts using signal processing and machine learning techniques. By integrating preprocessing methods, statistical feature extraction, and machine learning classification, the proposed frame- work effectively detects corrupted signals and improves signal reliability.

Experimental results demonstrate that the framework improves the accuracy of physio- logical monitoring systems. Future work will explore deep learning models and multimodal sensor data to further enhance signal reliability.

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