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From Noise to Knowledge: Investigating Pre-processing Techniques for Accurate Diagnosis of Heart and Brain Diseases

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ABSTRACT

Abstract: Healthcare data may or may not contain sensitive information. When it comes to keeping the data anywhere, it is quite easy, but when it comes to keeping the data systematically, the retrieval time becomes the lowest, the task is tedious. Due to unhealthy lifestyle, the number of patients is diagnosed with heart and brain diseases. A non-invasive method such as electrocardiogram (ECG) & Electroencephalogram (EEG) are used to monitor the health of the heart and brain respectively. ECG signals play a critical role in diagnosing various heart diseases like CAD, arrhythmia, whereas EEG signal is used to diagnose Alzheimer, epilepsy etc. at the initial stage, and a person's life can be saved by delivering an appropriate medication on time. Both ECG & EEG is a non-stationary signal, it has to be analysed within a time limit; otherwise, it is of no use. These signals are also impacted by different types of noise and artifacts, which necessitates the development of effective preprocessing techniques to enhance signal quality and extract relevant information. These preprocessing techniques are used to improve the interpretation of signals and helps in finding the abnormal patterns in the signals. The precision of diagnosing the heart and brain disease heavily depends on the preprocessed data. In this paper, common preprocessing techniques of ECG signals and EEG signals are discussed, which provides the useful insights in ECG & EEG signals for diagnosing heart and brain diseases. It also helps researchers and clinicians to choose suitable methods to enhance the accuracy of diagnosis.

Keywords: Alzheimer, Arrhythmia, Brain Disease, CAD, ECG, EEG, Heart Disease, Preprocessing

1. Introduction

Heart & brain diseases detection using electrocardiogram (ECG) and electroencephalogram (EEG) signals respectively has become a prominent area of research due to its non-invasive, cost effectiveness and particularly with the advancement of machine learning techniques. ECG is done by placing twelve electrodes on limbs and on portion of heart and EEG is done by placing electrodes on scalp as shown in figure 1. However, the correctness of the analysis heavily counts on the quality of the input signal. Preprocessing of ECG & EEG signals is a very important step which ensures the exclusion of different noises and artifacts, which results in enhancing the accuracy of heart and brain diseases classification classification (Houssein et. al.(2017), Jambukia et. al. (2015), Gregory et. al. (2016)). It also aims to mitigate the effects of artifacts and noises that interfere with the accurate analysis of the signals. ECG & EEG signals are generally affected by different forms of interference, such as baseline drift, muscle artifact, and powerline interference, due to which the reliability of systems for detecting heart and brain diseases can be compromised (Celin et. al. (2018), Syama et. al. (2019), Jovicic et. al. (2024)). Subsequently, preprocessing techniques are designed to improve and clean the ECG & EEG signals, and the consequence of preprocessing is that it preserves the critical features of signals for accurate classification. It may include filtering noise, normalizing data, and, as needed, converting signals into images to leverage both machine learning and deep learning algorithms (Chaddad et. al. (2023), Celin et. al. (2018).

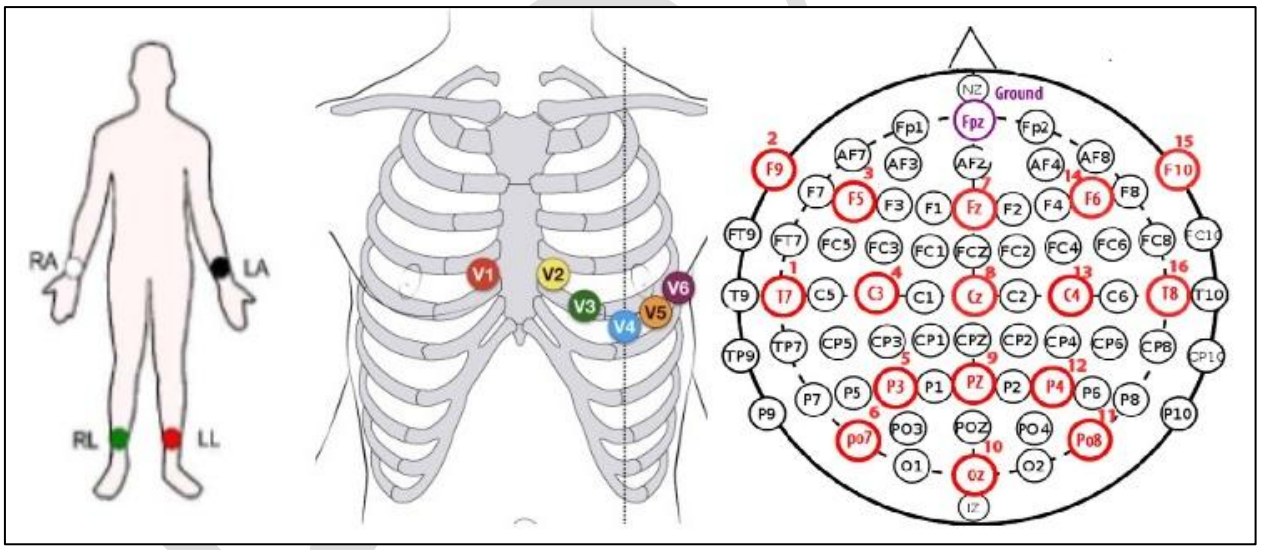

Figure 1: ECG electrode placement points on left and EEG electrode location on right

Machine learning models have been broadly used for ECG and EEG signal classification, as they provide robust methods for identifying insights in complex data. Malakouti, 2023) and (Jovicic, 2024) accentuated the role of machine learning models for analyzing ECG signals and EEG signals in the classification of heart and brain diseases. These models, provided with accurately pre-processed data, are capable of distinguishing among various heart ailments and brain ailments with great precision. By applying preprocessing methods, clinicians and researchers can make sure that ECG & EEG data input to analytic models is pristine, trustworthy, and optimized for efficient and effective classification of heart and brain diseases. This not only improves the reliability and performance of systems for the detection of heart and brain disease but also helps in improved clinical outcomes in early and precise diagnosis.

1. Types of noises in ECG and EEG Signals

ECG and EEG are contaminated by different sources of noises. Noises present in ECG signal affects the precise interpretation of heart beats or heart rhythms (Celin et. al. , 2018). Whereas EEG signals are affected by both internal and external sources of noise and contaminate the signals. Different types of noises are shown in table I (Marzog et.al. ,2022).

Table 1: Types of noise in ECG and EEG signal

	Types of noises	Frequency	Reason
EEG NOISE	Power line Interference	50 Hz or 60 Hz	Interference from electric equipment
	Eye Movements (EOG Artifacts)	1Hz to 2 Hz	Sudden blinking of eyes or eye movements
	Motion Artifacts	Variable Frequency	Movement of body or head
	Instrumentation noise	Spikes	
ECG NOISE	Baseline Wander	Less than 0.5 Hz	Due to respiration or body movement
	Powerline interference	50 Hz or 60 Hz	Noise from equipment
	EMG or Muscle Noise	20Hz to 300Hz	Contraction of muscles
	Electrode Motion Artifacts	Variable frequency	Due to movement of body or head

3. Preprocessing methods of EEG and ECG Signal

Preprocessing of ECG and EEG signals includes cleaning the raw signals by eliminating noise and artifacts. It processes the raw signal to improve the clarity and reliability of the signals. After preprocessing, the signals are ready for meaningful analysis and precise interpretation of disease. Both the signals, i.e., EEG and ECG, contain the different types of noise and artifacts listed in Table I. The main objective of the preprocessing is to remove or mitigate these unwanted components so that the clean signal can be analyzed (Usman et. al., 2022). Figure 2 shows the preprocessing framework for ECG and EEG signals.

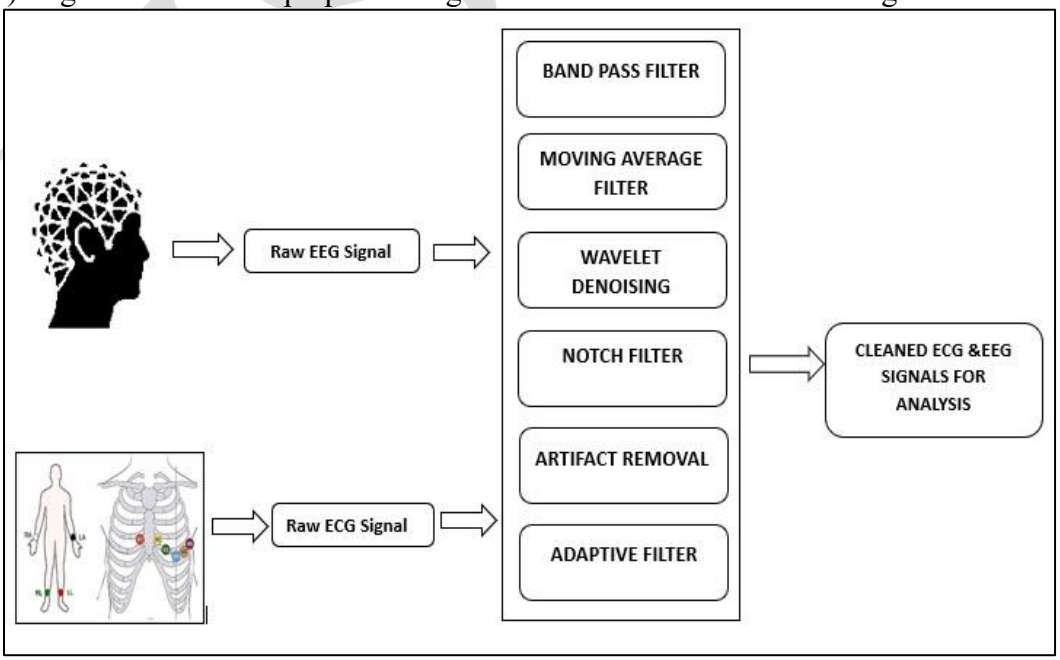

Figure 2: Preprocessing framework for ECG & EEG signals

3.1. Bandpass filter

Both ECG and EEG utilize bandpass filtering as a preprocessing method. It permits the transmission of frequencies within a specified range while attenuating those outside this range, so reducing noise and improving signal quality. We utilize it in EEG to delineate frequency ranges of interest, including alpha, beta, theta, delta, and gamma waves. These bands are associated with cognitive states and tasks. We use it to remove low-frequency (baseline wander) and high-frequency interferences (powerline interference & muscle noise) from ECG signals. To retain the P-wave, T-wave, and QRS complex, it employs a passband of 0.5 Hz to 150 Hz. (Al-Hindawi et.al., 2024, Samara et. al. , 2024)

3.2. Notch Filter

A notch filter is able to work on ECG and EEG signals. It is used to reduce the narrowband interference, like power line interference and baseline wander, from both the signals. In EEG it is used to preserve the frequency bands to get the clarity in neural signals for better assessment. Whereas in ECG signals, it is used to preserve the integrity of P-waves, T-waves, and QRS complexes for better analysis and detection (Lakehal et. al. , 2024).

3.3. Moving Average Filter

Moving average filter method is applicable to both EEG and ECG signals. It works on the consecutive data points and then averages a set of numbers in the window. In EEG it is used to smooth the data, but occasionally it also diminishes the signal components along with noise reduction. Therefore, window size and other parameters should be chosen carefully to preserve the signal. In ECG, it is used to mitigate the electromyographic interference from the signal and parallelly enhance the QRS complex for better analysis (Chowdary et. al. 2024, Malghan et. Al. 2020).

3.4. Wavelet Denoising

Wavelet denoising is applicable on ECG and EEG signals. It breaks down the signals into wavelet coefficients by using a threshold value. By breaking down the signal, noise can be suppressed and essential features of the signal are retained. In EEG, this method is used to neutralize the artifacts like eye blinks or muscle movements. It is also used to eliminate electrooculogram artifacts from the EEG signal (Prakash et. al. , 2024). In ECG, it is used to eliminate baseline wander, powerline interference, and motion artifacts by combining it with other techniques (Jabeur et. al, 2024).

3.5. Artifact Removal

Artifact removal can be applied to ECG and EEG signal. It is important to remove artifacts such as muscle movements, eye blinking or opening, and environmental noise. In EEG different methods can be used to remove artifacts like independent component analysis (ICA), wavelet transform, and empirical mode decomposition. In ECG, adaptive filtering, notch filtering, and wavelet denoising can be used to remove the artifacts present in the signal. Artifact removal is employed to filter the clean signals from raw signals (Prakash et. al. , 2024, Chuang et. al., 2024).

4. Result and Discussions

In this section experimental results are discussed. All the experiments are performed with the help of python tool. For ECG analysis, arrhythmia disease dataset (Link 1) is used for performing the preprocessing techniques discussed in section 3. Whereas for EEG analysis, Alzheimer disease dataset (Link 2) is used. Preprocessing results of ECG and EEG are shown below in figure 3 and figure 4 respectively. These methods are compared on the basis of Signal to Noise ratio (SNR) for method selection and the SNR ratio is shown in Table II

Table 2: SNR of ECG and EEG signals

Preprocessing methods	EEG (SNR)	ECG(SNR)
Bandpass Filter	18.67db	16.56db
Notch Filter	36.07db	34.56db
Average Moving Filter	8.75db	9.33db
Wavelet Denoising	24.59db	27.23db
Artifact Removal	12.33db	18.47db

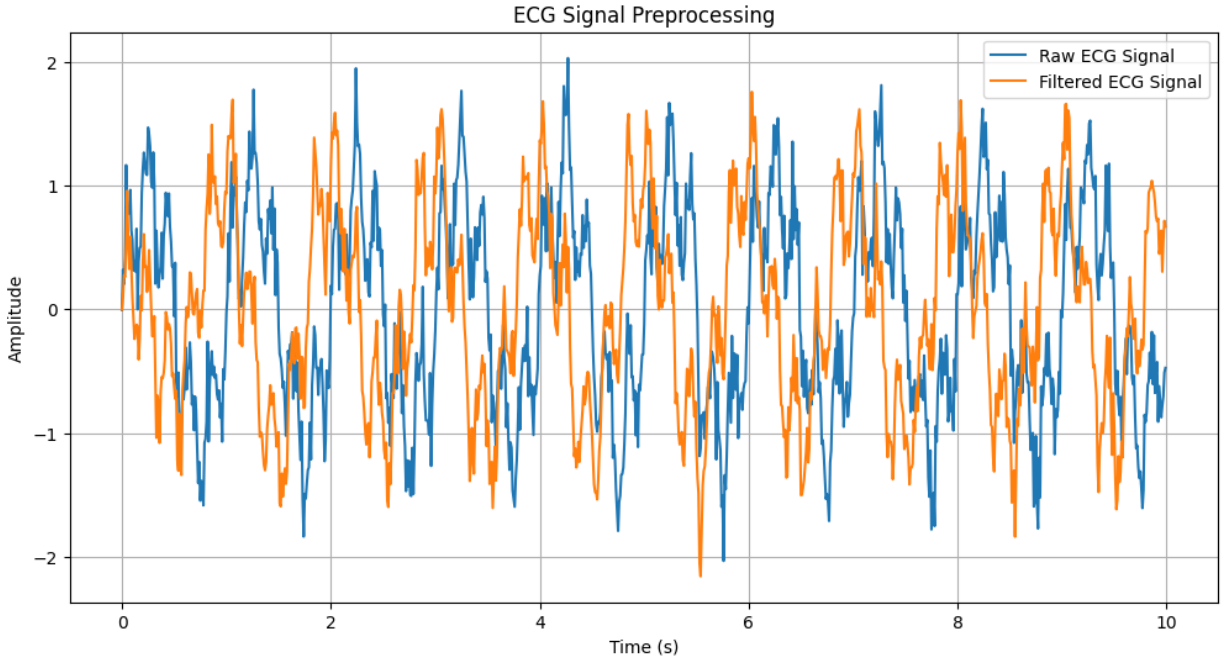

Figure 3: Preprocessing of ECG signal

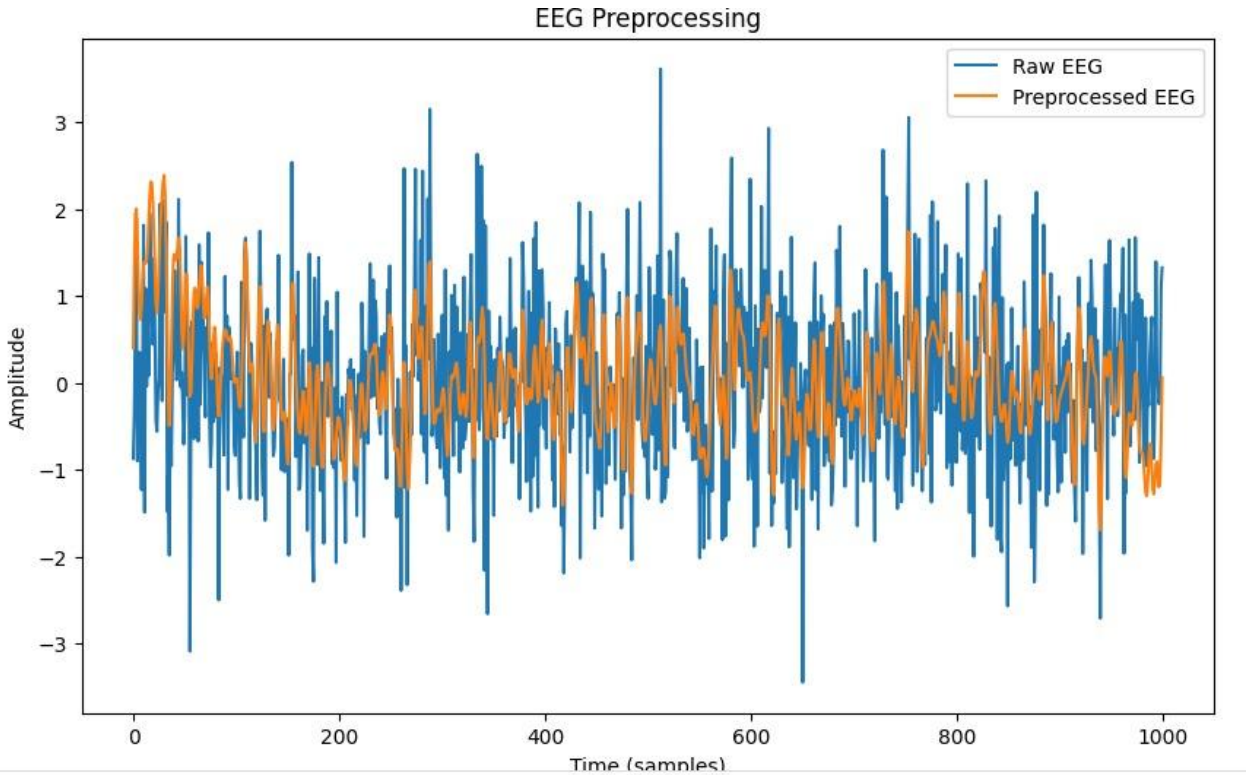

Figure 4: Preprocessing of EEG signal

5. Conclusion

This article has explained the various ECG and EEG signal preprocessing techniques, explaining their benefits towards improved data quality and analysis of brain and heart activities. This article also explains about different artifacts and noises present in ECG and EEG signals along with their frequency ranges and various causes for their appearance in the signal. By comparing the signal to noise ratio, the notch filter and wavelet denoising filter performed well with ECG and EEG signals respectively. By using different preprocessing techniques, researchers can effectively remove different artifacts and noises from basic signals, which helps in preserving the essential information.

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