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RESEARCH ARTICLE

Acquisition and Analysis of Cardio Graphic Signal Using Various Transforms

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ABSTRACT

In the modern days, cardiac problems among various age group people have increased by a large ratio. Electro cardiograph is widely used to monitor the electrical activities of the heart. With the help of ECG, we can able to easily detect and classify the irregular activities of the heart. Hence in this study, we have acquired ECG signals from ten different subjects of various age groups using the BIOPAC system. All the acquired ECG signals are pre-processed using the infinite impulse response bandpass filter. Then the most vital R wave is detected by using the peak detection method present in-built in the BIOPAC system. This R wave detection plays a very vital role in diagnosing heart rhythm irregularities, calculating the heart rate variability, recognizing the heart rate variability, and measuring the heart rate. The pre-processed ECG signal is processed using highly advanced windowing techniques to extract the power spectrum and frequency-based values of the ECG signal. The results of the Fourier transform and spectral density of the processed ECG signals are displayed in this study. The features extracted from ECG signals acquired from ten different subjects have been tabulated in this study.

Keywords: BIOPAC system and Peak detection, Electro cardiography, Heart rate variability, R wave.

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1. Introduction

Electrocardiogram is generally termed as ECG which is generally used to measure the electrical activity of the heart. These electrocardiogram signals are one of the most important biomedical signals because they are reflective of the electrical activity of the heart. These ECG signals are one of the well-defined signals and the most important source of diagnostic information. The electrical activity in the heart is generated by using the sinus node. The irregularities in the generation of cardiac electrical activities lead to tachycardia and bradycardia. Tachycardia is the state at which the electrical activities of the heart have been increased which leads to an increase in the heart beat rate per minute and then bradycardia is the state at which the cardiac electrical activities have been decreased which leads to a decrease in the heart beat per minute. Generally, the BPM is calculated from the ECG signal by detecting the R wave peaks in the signal for the period of one minute. The R wave represents the ventricular depolarization of the heart. As the ventricular walls are very thick a high voltage of electrical impulse is required for the contraction of the ventricles. This high voltage required for the contraction of the ventricles is denoted as the R wave. This R wave is identified in this study by using the peak detection tool which is built into the BIOPAC system. All the acquired ECG signals from the various subjects have been pre-processed using the IIR band pass filter. The band pass filter is applied in this study to denoise the unwanted noises present in the acquired ECG signal. The denoised ECG signal is smoothened using the mean average smoothening window to remove the minute artifacts present in the filtered signal. All the ECG signals are processed using the FFT and the PSD transform to extract the features from the pre-processed ECG signals. In this study, the FFT transform is widely used to convert the time domain ECG signal to the frequency domain ECG signal to analyse the frequency domain values. From the frequency domain signals, we can able to extract the features related to the frequency domain of the pre-processed ECG signal. The power spectral density is applied in this study to find the power spectral values of the acquired ECG signal. The PSD transform helps in determining the power spectrum values of the acquired ECG signal. The peak detection tool present in the BIOPAC system helps in the detection of the R wave peak in the acquired ECG signal. The R wave present in the recorded ECG shows the ventricular depolarization of the heart. Generally, the R wave is calculated to diagnose the heart rate variability and for the measurement of the heartbeat per minute. These R waves also play a very vital role in the recognition of heart rate variability and detecting the arrhythmias of the heart. Heart variability (HRV) is referred to as the fluctuations in the time intervals between adjacent heartbeats. HRV basically indexes neurocardiac function. This neurocardiac function is generated by the brain and passed to the heart for its regulation. In this study, the FFT and PSD transform of the R wave are clearly shown and the features of the FFT and PSD are tabulated. The main goal of this study is to extract the vital features from the ECG signal for quick analysis to find the abnormalities.

2. Literature Review

Duskalov *et al*. performed normal procedures for the acquisition of the ECG signal and performed pre-processing and several analyses of the acquired signal in an economical way. Even though this system provides an economical way of analysis of the signal [1]. Abdourahmane *et al*. proposed a study in which ECG signals are acquired and pre-processed using the wavelet transform. In this study, the noises are removed from the acquired signal to get better accuracy [2]. Duskalov *et al*. proposed a study for automatic detection of the QRS onset and offset. This system has a very reasonable accuracy level due to the interference of several artifacts [3]. Afonso designed a digital signal processing algorithm for the detection of the heartbeat. This algorithm consists of filter banks that decompose the acquired ECG signal into subbands with a uniform frequency bandwidth [4]. Zhu *et al*. proposed an application of a low pass filter in the pre-processing of the ECG signal. This proposed system uses Marr wavelet to decompose and Mallat algorithm for filtering the ECG signal [5]. Nayak *et al*. discussed the several digital signal filtering techniques involved in the filtering of the most sensible ECG signals [6]. Ekinci *et al*. discussed the several filters that have been employed in the pre-processing of the ECG signal [7]. Israel *et al*. developed a system that states the features that are extracted from the cardiac signal are unique to an individual. This system employs several filters for identifying the fiducial point [8]. Berkaya *et al*. discussed the several techniques that are involved in the ECG signal pre-processing, processing, feature extraction, feature transformation, and classification [9]. Sornmo *et al*. clearly discussed the several basic sets of algorithms that have been employed in the removal of various types of noises present in the ECG signal [10]. Singh and Krishnan extracted the features of the ECG signal with respect to the time domain, frequency domain, and time-frequency domain [11]. These above-mentioned defects are successfully overcome in this study with the help of BIOPAC system for acquiring the signals, inducing a highly efficient bandpass filter for pre-processing the acquired signal, and applying advanced transforms for the feature extraction.

3. Signal Acquisition and Methodology

In this study, the electrocardiogram (ECG) signals are acquired from the ten normal subjects of the age group 18 to 22. These signals are acquired from the subject at their resting position. All the ECG signals used in this study are acquired using the BIOPAC system present in the Biomedical Engineering Centre for Excellence laboratory. From each subject three different states of signals are acquired for the analysis in this study. All the subjects employed in this study are normal individuals of the age group 18 to 22 with efficient cardiacfunction. The detaied report of the subjects are clearly tabulated in the Table I. The study groups are requested to be at the resting state for a period of thirty minutes before the acquisition of the signal. These signals are acquired from the subjects by placing the surface electrodes at the subject's left arm, left leg, and right leg:

- Positive electrode is connected to the left leg.
- Negative electrode is connected to the right arm.
- Ground electrode is connected to the right leg

Three different types of ECG signals were acquired in this study for the analysis:

- Calibration signal
- Resting state signal
- Signal acquired after a slight physical exercise

All the acquired signals in this study are pre-processed and processed based on the needs. The methodolgy implied in this study is shown in the Fig. 1.

In this study, all the acquired ECG signals are pre-processed using the IIR band pass filter for denoising the noises present in the acquired ECG signal. The

TABLE I: Details of the Subjects Employed in This Study

SI. No	Subject ID	Subject age	Subject gender
1	SUBJECT ID 01	19	Male
2	SUBJECT ID 02	22	Female
3	SUBJECT ID 03	21	Male
4	SUBJECT ID 04	19	Male
5	SUBJECT ID 05	18	Male
6	SUBJECT ID 06	21	Male
7	SUBJECT ID 07	20	Female
8	SUBJECT ID 08	20	Female
9	SUBJECT ID 09	21	Male
10	SUBJECT ID 10	22	Female

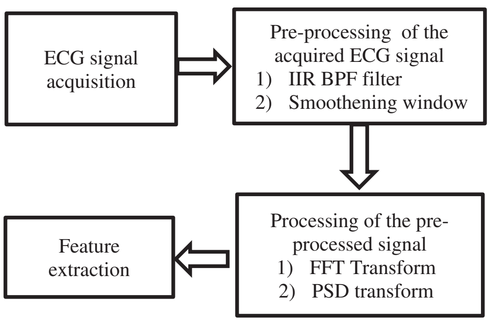

Fig. 1. Methodology of the study.

TABLE II: Vital Parameters Extracted from the Pre-processed ECG Signal

Si. NO	Signal detail	P-P	Mean	Max	Std dev	BPM
1	Mean of all the acquired signals	0.75 Mv	0.004 Mv	0.368 Mv	0.138 Mv	6.127 BPM

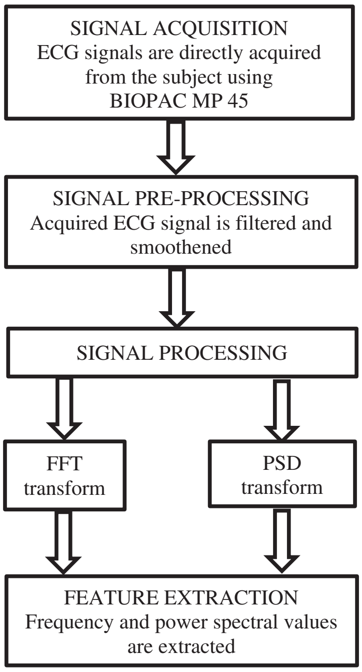

Fig. 2. Workflow of the study.

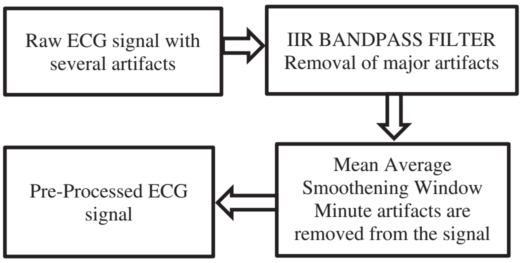

Fig. 3. ECG pre-processing methodology.

filtered ECG signal is smoothened using the mean average smoothening window method to remove the minute artifacts present in the filtered ECG signals. All the pre-processed ECG signals are processed using FFT and PSD transform. In this study the FFT transform is used to convert the time-domain ECG signal to the frequency-domain signal and the PSD transform is used to find the power spectral range of the signal. Using the FFT and PSD transform the most vital frequency and the power spectrum parameters of the ECG signals are extracted and analyzed in this study. The clear flow of the study is explained using the flow chart in the Fig. 2.

4. ECG Signal Pre-processing

In this study, signal pre-processing is generally referred to as the denoising of the noises from the acquired ECG signal. The entire signal pre-processing methodlogy is explained in the Fig. 3. Generally, the acquired ECG signals consist of noises that arise due to the overlapping of the respiratory signals, loose electrode placement, and motion artifacts. These unwanted noises are removed from the signal at the stage of signal pre-processing. The vital parameters extracted from the pre-processed ECG signal are tabulated in the Table II.

4.1. IIR Bandpass Filter

The first stage for pre-processing of the ECG signal is the IIR band pass filter. In this stage, the unwanted noises present in the acquired ECG signals are filtered and the signals are freed from the noises. The bandpass filter in this study works by allowing the signals within a selected range of frequencies to be decoded while preventing the signals at the unwanted frequency from getting through. The BPF cutoff frequency is set from 0.5 Hz to 150 Hz for the filtering process. The lower frequency cutoff is set as 0.5 Hz and the higher cut-off frequency is set as 150 Hz for the filtering of the acquired ECG signal. A difference between the raw ECG signal with artifacts and band pass filtered signal is clearly shown in the Figs. 4 and 5.

4.2. Smoothening Window

The second stage for pre-processing of the ECG signal is a mean average smoothening method. In this stage, the filtered ECG signal is smoothened to remove the roughness of the signal. In this study the smoothening window works by modifying the data points of the filtered ECG signal which are slightly higher than the immediate adjacent data points. The increase in the data points is due to the minute artifacts. These minute artifacts or noises are removed from the filtered ECG signal in this step to obtain a noise-free pre-processed ECG signal. The output of the smoothening window will be a pure noise free ECG signal which is displayed in Fig. 6.

5. ECG Signal Processing

The signal processing of ECG signal in this study is achieved with the help of the most advanced signal processing tools present in the BIOPAC system. The entire ECG signal processing methodolgy is outline in the block diagram shown in the Fig. 7. The advanced signal processing tools present in this system are FFT and PSD transforms. Generally, these transforms are used to convert the time domain pre-processed signal to the frequency domain signal and to extract the power spectrum range of the signal.

5.1. FFT Transform

Fast Fourier transform is the advanced version of the discrete Fourier transform. FFT is the fastest method for the conversion of the time domain signal to the frequency domain signal compared to the DFT. FFT is widely used in the processing of continuous signals hence, it is used in this study, for ECG signal processing. The major function of the FFT transform using the hamming window

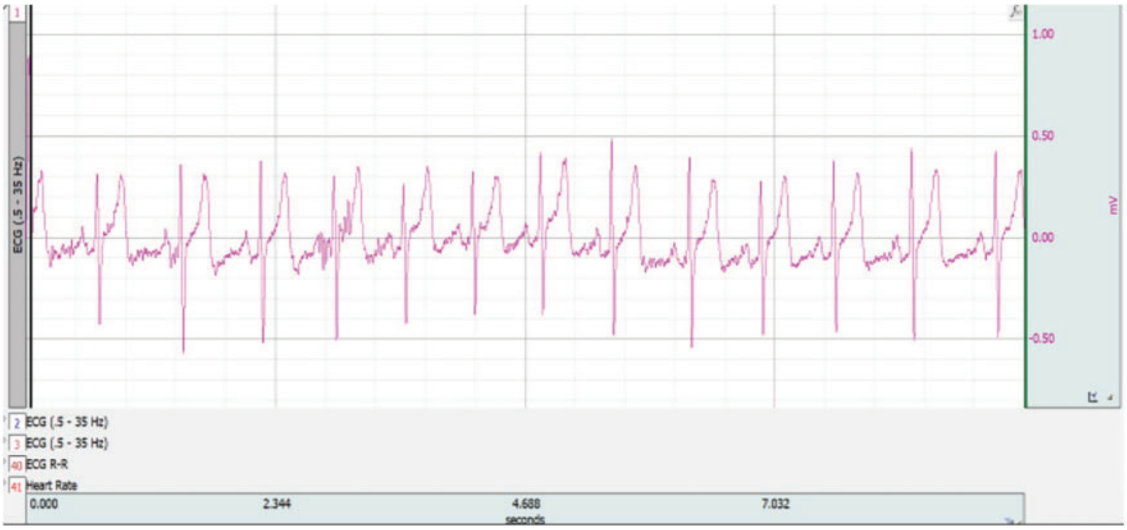

Fig. 4. ECG signal with artifacts.

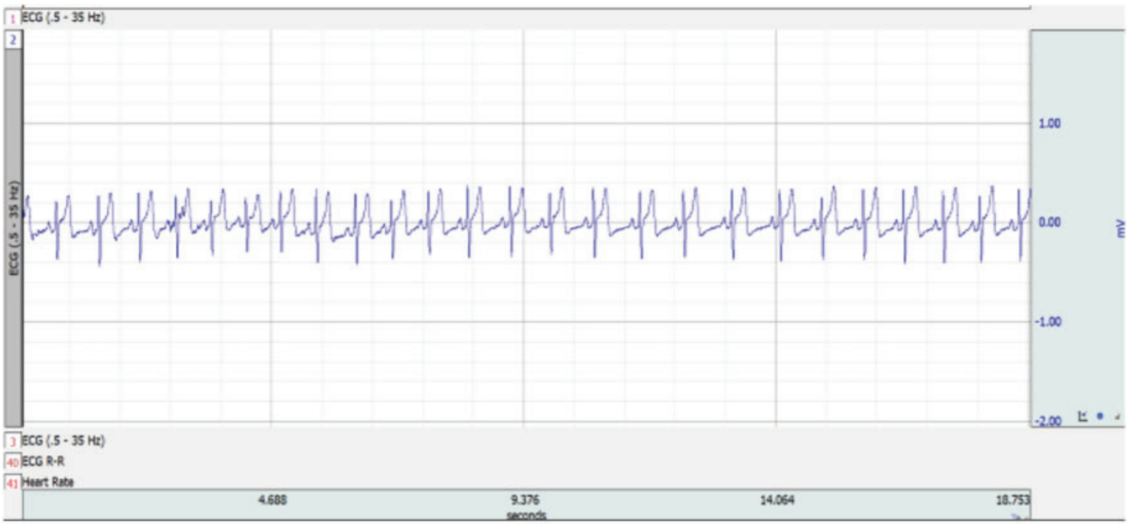

Fig. 5. Filtered ECG signal.

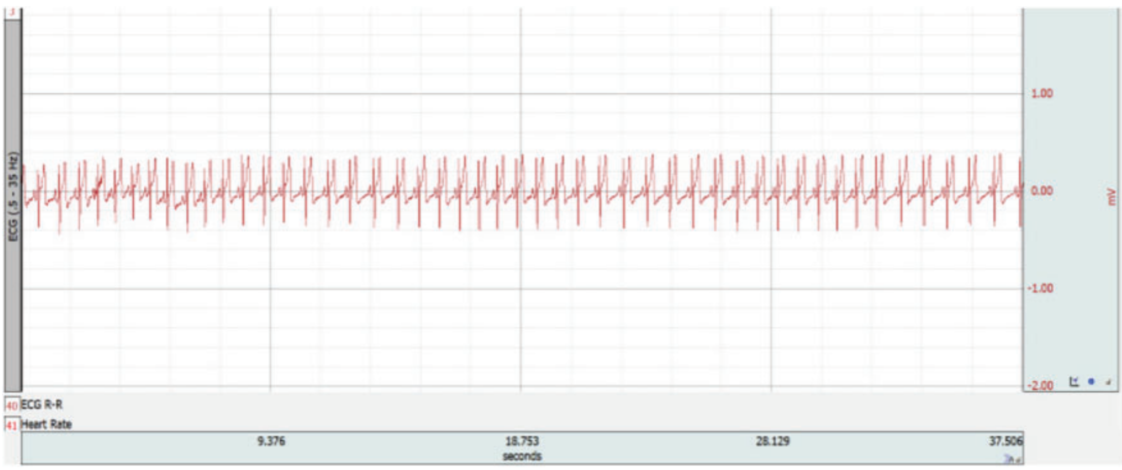

Fig. 6. Smoothened ECG signal.

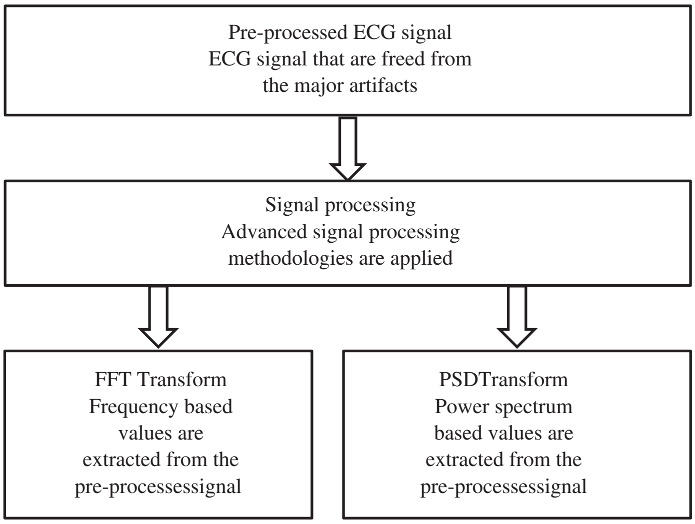

Fig. 7. ECG signal processing methodology.

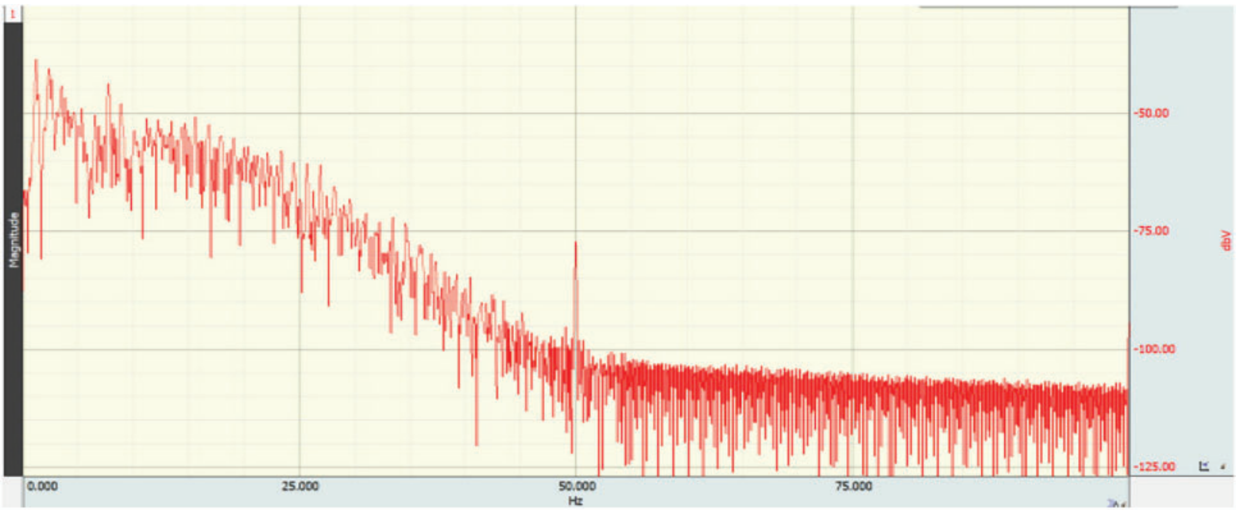

Fig. 8. FFT transform of the pre-processed ECG signal.

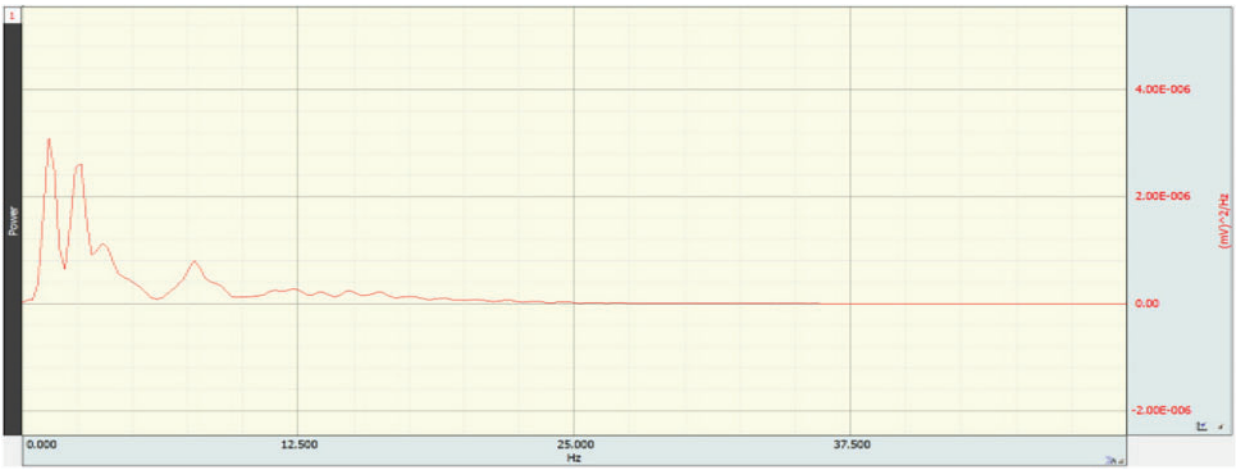

Fig. 9. PSD transform of the pre-processed ECG signal.

TABLE III: Vital Parameters Extracted from the FFT Transformed Signal

Si. NO	Signal detail	Delta F	Min F	Max F	Median F	Freq
1	Mean of all the acquired signals	51.452 Hz	52.124 Hz	2.30 Hz	18.432 Hz	52.85 Hz

TABLE IV: Vital Parameters Extracted from the PSD Transform

Si. NO	Signal detail	P-P Mv2/Hz	Mean Mv2/Hz	Max Mv2/Hz	Std dev Mv2/Hz	Median Mv2/Hz
1	Mean of all the acquired signals	3.08	2.97	3.08	5.37	1.17

method in this study is to convert the time domain of the ECG signal to the frequency domain signal to extract the frequency-related features of the acquired electrocardiographic signal. The FFT transform for the acquired ECG signal is clearly shown in the Fig. 8.

5.2. PSD Transform

Power spectral density transform is one of the most advanced signal processing tools present in the BIOPAC system. PSD in the BIOPAC system is widely used to find the power spectral density of the biosignals. The power spectral density of the ECG signal is calculated in this study by dividing the frequency of the pre-processed ECG signal by the square of the electrical potential of the pre-processed ECG signal. The major function of the PSD transform in this study is to extract the power spectral density features of the acquired ECG signal. The output for the PSD transformed pre-processed ECG signal is shown in Fig. 9.

6. Results and Discussion

All the acquired ECG signals from the subjects are pre-processed to remove the artifacts present in the signal. Then the pre-processed ECG signals are processed using the advanced signal processing tools to extract the vital features from the acquired ECG signal.

6.1. Pre-Processing of the ECG Signal

At the stage of pre-processing the artifacts present in the signals are removed by using the bandpass filter and the roughness of the signals is smoothened using the mean average smoothening window.

6.2. FFT Transform

The FFT transform is used to convert the pre-processed time domain signal to the frequency domain signal to extract the vital frequency parameters. The frequency based values extracted from the FFT transformed signal is tabulated in the Table III.

6.3. PSD Transform

PSD transform is applied to the pre-processed ECG signal in this study to extract the power spectral density of the acquired ECG signal and to extract the vital power spectral density parameters of the ECG signal. The vital power spectral based parameters extracted from the output of the PSD transformed signal is tabulated in the Table IV.

7. Conclusion

In this study, nearly thirty electrocardiographic signals are acquired from the ten different subjects of the age group 18 to 22. All the acquired ECG signals are filtered using the infinite intrinsic response band pass filter for the removal of the unwanted artifacts present in the acquired ECG signal and then the roughness of the ECG signals are smoothened using the mean average smoothening window. These pre-processed ECG signals are processed using the advanced FFT transform for the conversion of the time domain signal to the frequency domain signal to extract the frequency-related parameters of the ECG signal and then the PSD transform is used for the extraction of power spectral density of the pre-processed ECG signal to obtain PSD parameters of the ECG signal. All the most vital FFT and PSD parameters of the ECG signals are acquired and tabulated in this study. The main goal of this study is achieved successfully and this study paves the way for the betterment of the ECG signal analysis in the future in an economical way.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

References

[1] Duskalovl IK, Dotsinsky IA, Christov II. Developments in ECG acquisition, pre-processing, parameter measurement and recording. *IEEE Eng Med Biol Mag*. 1998;17(2):50–8.

[2] Abdourahman, Mandy G, Ouya S. ECG signal acquisition and pre-processing system based on the wavelet transform. *Fourth International Conference on Multimedia Computing, Networking and Applications*. IEEE, 2020.

[3] Duskalov IK, Christov II. Electro cardiograph signal pre-processing for automatic detection of QRS boundaries. *Med Eng Phy*. 1999;21(1):37–44.

[4] Afonso VX, Tompkins WJ, Nguyen TQ, Luo S. ECG beat detection using filter banks. *IEEE Trans Biomed Eng*. Feb 1999;46(2): 192–202.

[5] Zhu J, Zhang X, Wang Z, Wang X. Pre-processing and analysis of the ECG signals. *Seventh International Symposium on Instrumentation and Computer Technology*, 2008.

[6] Nayak S, Soni Mk, Bansal D. Filtering techniques for ECG signal processing. *Int J Res Eng Appl Sci*. 2012;2:671–9.

[7] Ekinci G, Kardes E, Guvenkaya H, Karagoz P. Investigating the pre-processing methods in ECG analysis. *29th Signal Processing and Communication Application Conference*, 2021.

[8] Israel SA, Irvine JM, Cheng A, Widerhold MD, Widerhold BK. ECG to identify individuals. *Patten Recognit*. 2005;38(1):133–42.

[9] Berkaya SK, Uysal AK, Gunal ES, Ergin S, Gunal S, Gulmezoglu MB. A survey on ECG signal analysis. *Biomed Signal Process Control*. 2018;43:216–35.

[10] Sornmo L, Laguna P. Electrocardiogram (ECG) signal processing. *Wiley Encycloped Biomed Eng*. 2006. doi: 10.1002/9780471740360.ebs1482.

[11] Singh AK, Krishnan S. ECG signal feature extraction trends in methods and applications. *Biomed Eng Online*. 2023;22(1):22. doi: 10.1186/s12938-023-01075-1.