PPG Analysis Report

1. Introduction

The goal of this project is to perform analysis on PPG (Photoplethysmogram) signals to extract relevant features, detect arrhythmia, calculate heart rate, respiratory rate, and systolic amplitude, and generate visualizations. The PPG signals are processed, and key features are extracted for further diagnostic purposes.

This report covers the implementation details, methods used for feature extraction, arrhythmia detection, and the results generated from analyzing the datasets.

2. Project Overview

The PPG signal analysis pipeline includes the following main steps:

1. **Data Loading**: Reading PPG signal data from CSV files.
2. **Preprocessing**: Filtering and correcting the PPG signals for noise reduction and normalization.
3. **Feature Extraction**: Extracting features such as heart rate, respiratory rate, and systolic amplitude.
4. **Arrhythmia Detection**: Identifying irregularities in the heart rate and abnormal waveforms indicative of arrhythmia.
5. **Results**: Generating output files that include extracted features and arrhythmia detection results.
6. **Visualization**: Creating plots for signal visualization and feature distributions.

3. Requirements

3.1 Hardware Requirements

- A computer with at least 4GB of RAM.
- Processor: 2.0 GHz or faster recommended.

3.2 Software Requirements

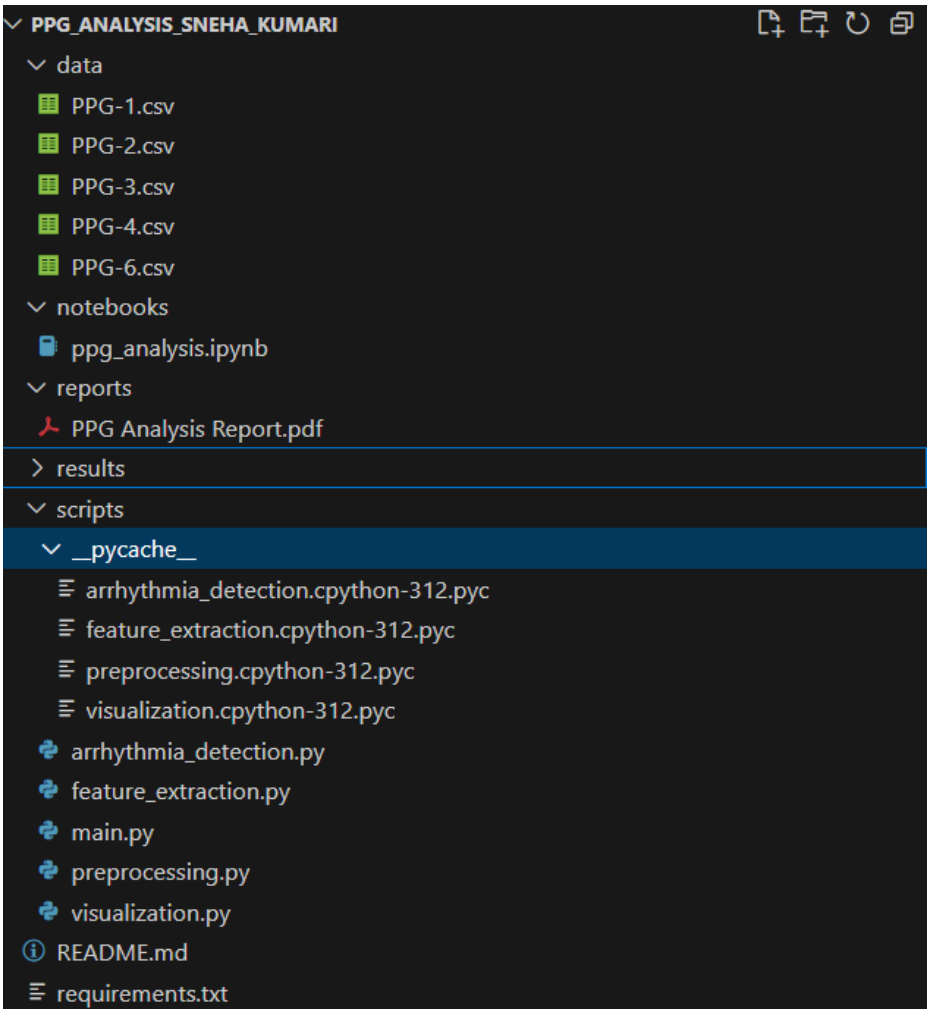
- Python 3.7 or higher
- Required libraries:
    - numpy
    - pandas
    - matplotlib

- scipy
- Custom modules: preprocessing, feature_extraction, arrhythmia_detection, visualization

These libraries can be installed using pip:

```
pip install numpy pandas matplotlib scipy
```

3.3 Folder Structure



4. How to Run the Analysis

4.1 Preparing the Environment

1. Clone or download the project files.
2. Install the necessary Python dependencies using pip.

4.2 Running the Code

1. Ensure you have the required data files in the data/ directory. The files should be CSV files starting with "PPG-" (e.g., PPG-1.csv, PPG-2.csv).
2. Open a terminal and navigate to the scripts/ directory.
3. Run the following command to execute the analysis:

   python main.py

4.3 Output

After running the code, the results will be saved in the results/ directory. Each dataset will have:

- A CSV file with the extracted features and arrhythmia detection results.
- Plots for the PPG signal and feature distributions.

The output CSV will contain columns like:

- Feature: Name of the extracted feature.
- Value: Value of the feature.
- Irregular Heart Rate: Boolean indicating if arrhythmia was detected.
- Abnormal Waveform: Boolean indicating abnormal waveform detection.
- Mean Heart Rate: Average heart rate calculated from the PPG signal.
- Mean Respiratory Rate: Average respiratory rate.
- Mean Systolic Amplitude: Average systolic amplitude.
- Segment Time Start: Start time of the arrhythmia segment (if detected).
- Segment Time End: End time of the arrhythmia segment (if detected).

Additionally, signal and feature distribution plots will be saved as PNG files.

5. Methodology

5.1 Data Loading

The data is loaded using the load_data() function, which reads CSV files containing PPG signal data. The sampling rate and duration of the signal are also extracted.

5.2 Preprocessing

The preprocess_signal() function applies filters to remove noise and smooth the signal, ensuring that it is ready for analysis. The correct_ppg_signal() function normalizes the signal to adjust for any inconsistencies.

5.3 Feature Extraction

Key features like heart rate, respiratory rate, and systolic amplitude are calculated:

- **Heart Rate**: The number of heartbeats per minute.
- **Respiratory Rate**: The number of breaths per minute.
- **Systolic Amplitude**: The amplitude of the PPG signal during systole.

These features are extracted using the extract_features() function, and the calculate_heart_rate(), calculate_respiratory_rate(), and calculate_systolic_amplitude() functions.

5.4 Arrhythmia Detection

The detect_arrhythmia() function analyzes the PPG signal to detect arrhythmia by identifying irregular heart rates and abnormal waveforms. The time segment where arrhythmia is detected is saved for further analysis.

5.5 Visualization

The plot_signal() function generates plots of the PPG signal, and the plot_feature_distribution() function plots the distribution of extracted features. These visualizations help to interpret the data and validate the analysis.

6. Results and Observations

6.1 Mean Heart Rate

The average heart rate for each dataset was computed and reported in beats per minute (BPM). This is a crucial measure for assessing overall cardiovascular health.

6.2 Mean Respiratory Rate

The respiratory rate was calculated and reported as the number of breaths per minute. Abnormal respiratory rates could indicate issues with the patient's breathing or circulation.

6.3 Mean Systolic Amplitude

The systolic amplitude was calculated as an indicator of the strength of the heart's contraction. Lower amplitudes may indicate cardiovascular issues.

6.4 Arrhythmia Detection

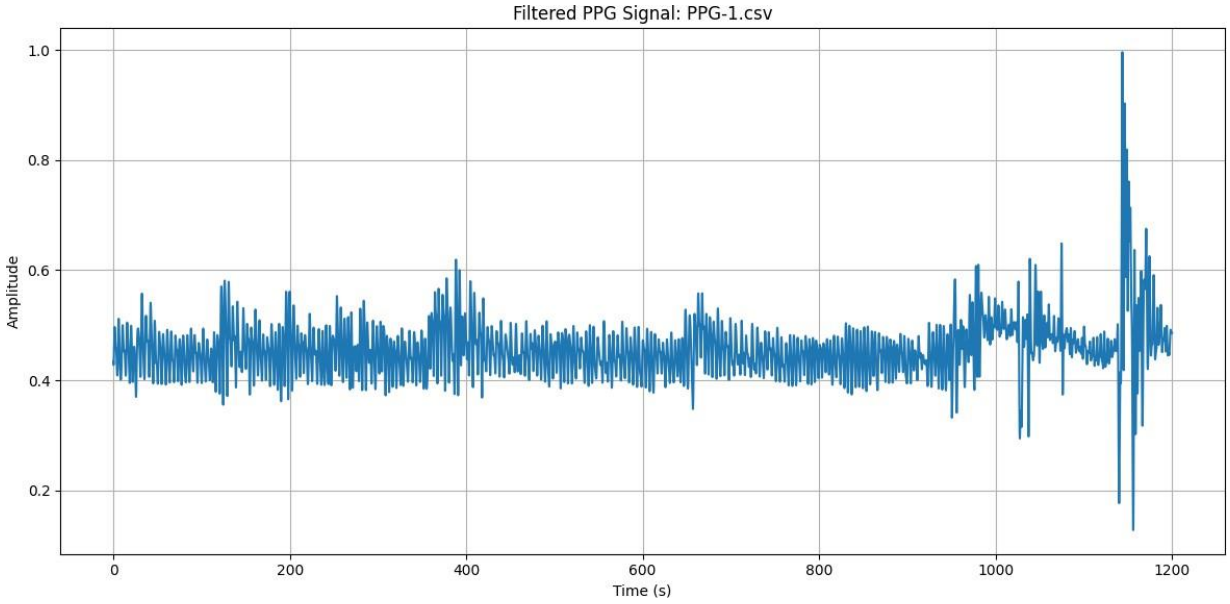
Arrhythmia was detected in some datasets, with the segment time during which arrhythmia was detected recorded. The presence of arrhythmia was flagged in the results.

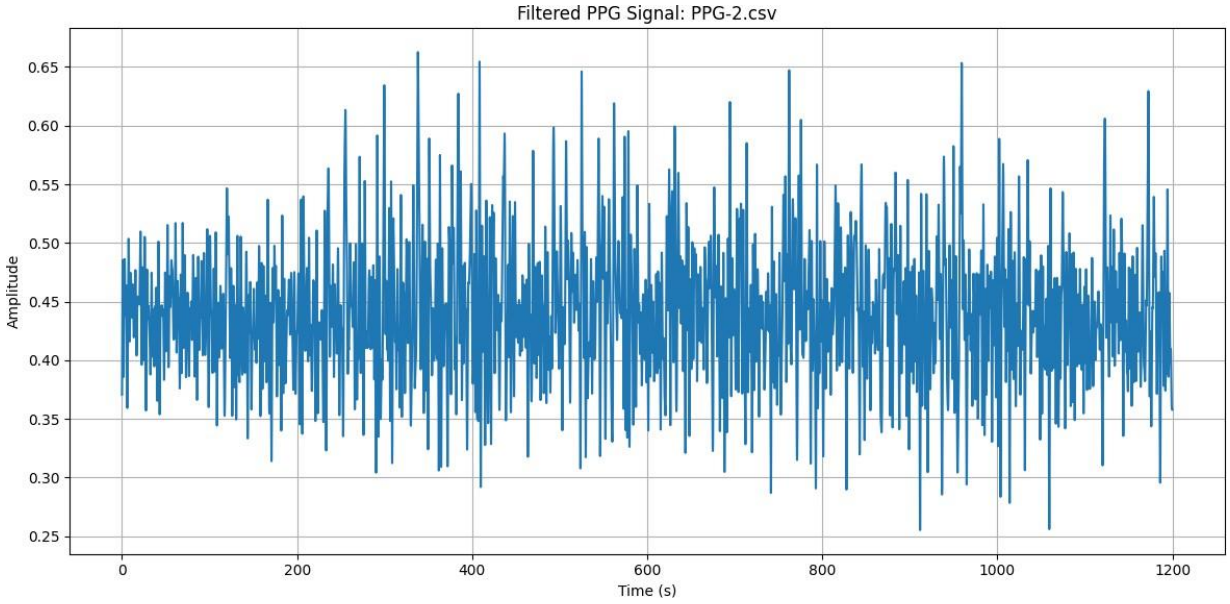
7. Conclusion

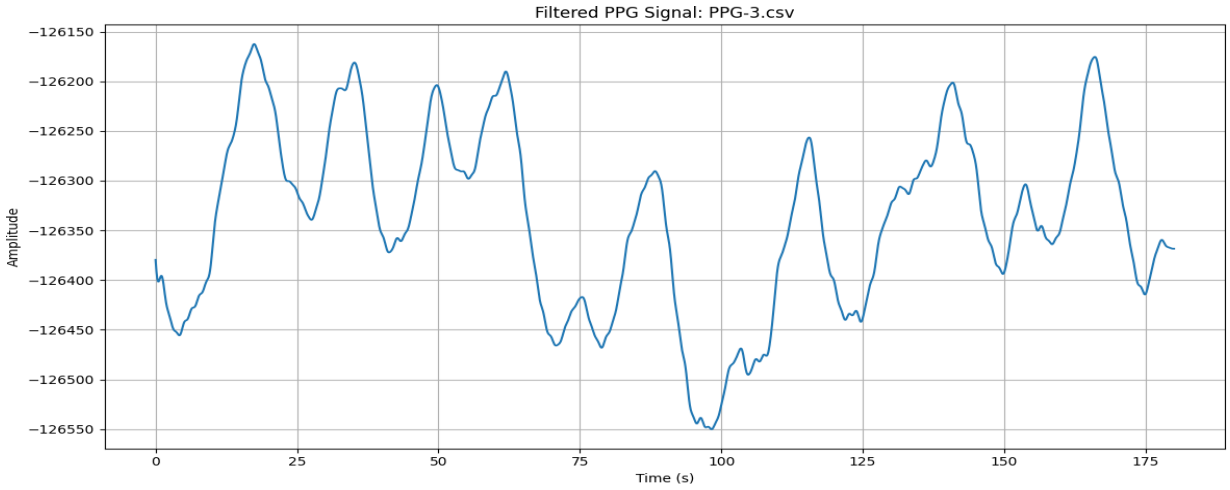
This analysis demonstrates the capability of processing PPG signals to extract valuable features for cardiovascular health monitoring. The implemented methods for arrhythmia detection and feature extraction provide useful insights that can be used for further medical diagnostics.

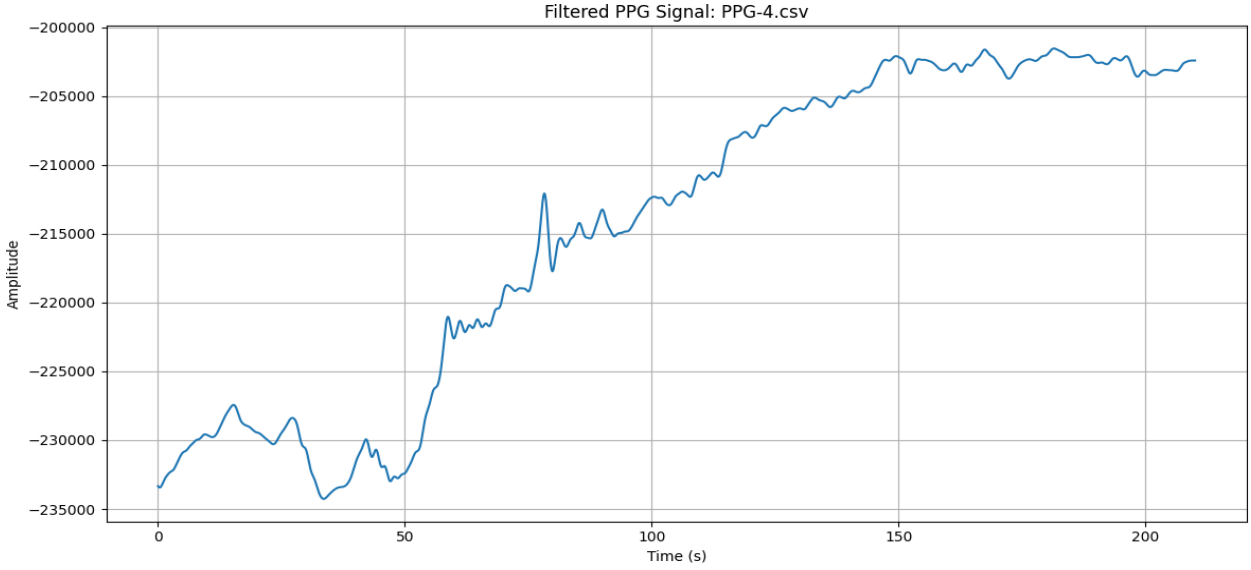
8 . Results and Observations

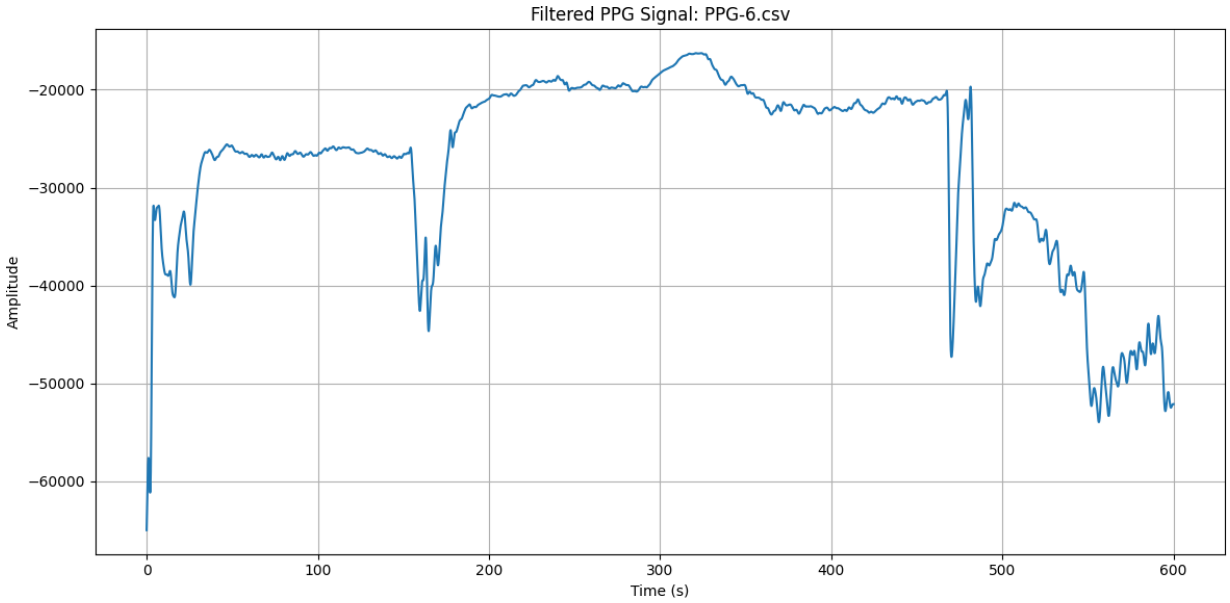
```
Dataset: PPG-1.csv, Sampling Rate: 125 Hz, Duration: 20 Minutes
Dataset: PPG-2.csv, Sampling Rate: 125 Hz, Duration: 20 Minutes
Dataset: PPG-3.csv, Sampling Rate: 100 Hz, Duration: 3 Minutes
Dataset: PPG-4.csv, Sampling Rate: 100 Hz, Duration: 210 Minutes
Dataset: PPG-6.csv, Sampling Rate: 128 Hz, Duration: 10 Minutes
```





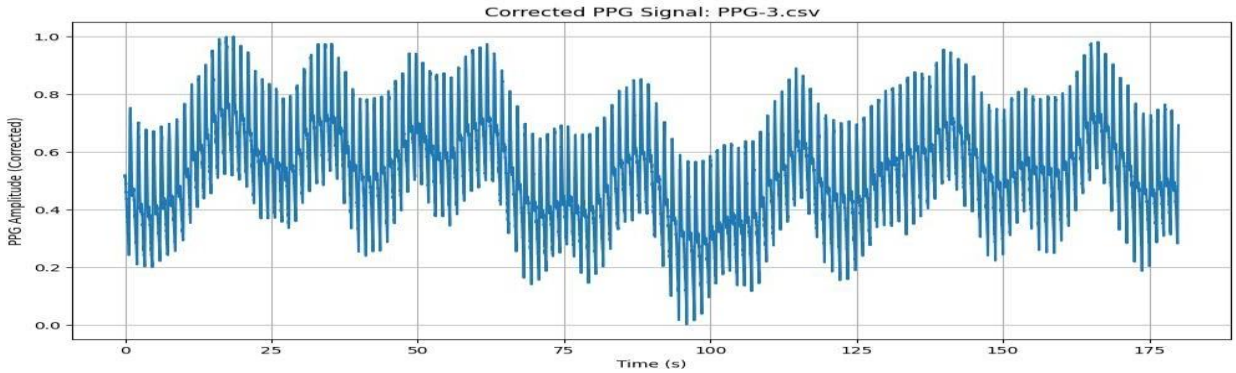

Filtered PPG Signal: PPG-3.csv
Amplitude
Time (s)
−126150
−126200
−126250
−126300
−126350
−126400
−126450
−126500
−126550
0
25
50
75
100
125
150
175

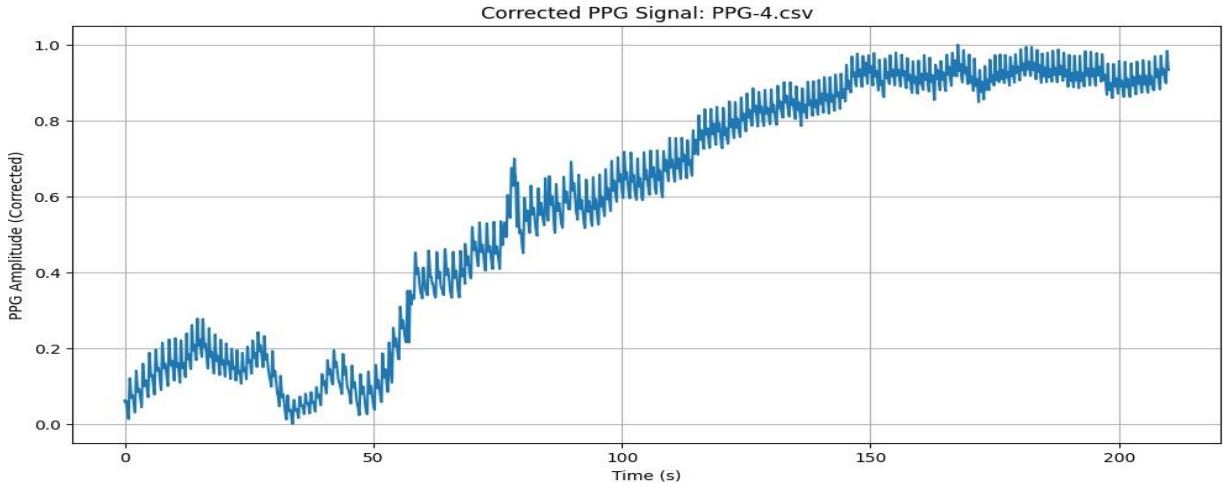

Filtered PPG Signal: PPG-4.csv
Amplitude
Time (s)
−200000
−205000
−210000
−215000
−220000
−225000
−230000
−235000
0
50
100
150
200

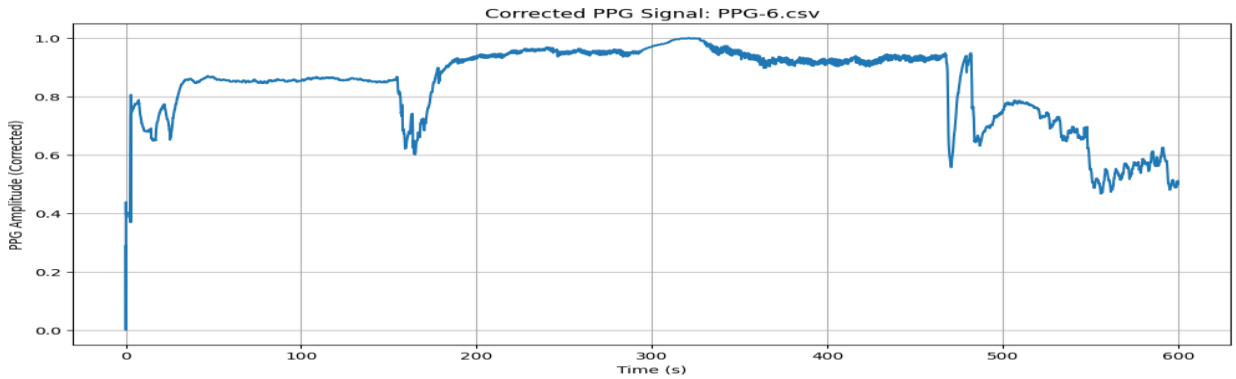

Filtered PPG Signal: PPG-6.csv
Amplitude
Time (s)
−20000
−30000
−40000
−50000
−60000
0
100
200
300
400
500
600

```
Dataset: PPG-1.csv, PPG Min: 0.0, PPG Max: 1.0
Dataset: PPG-2.csv, PPG Min: 0.110459433, PPG Max: 0.99315738
Dataset: PPG-3.csv, PPG Min: -126795.0, PPG Max: -125954.0
Dataset: PPG-4.csv, PPG Min: -235356.0, PPG Max: -199805.0
Dataset: PPG-6.csv, PPG Min: -87320.41406, PPG Max: -16220.49414
```

After Noramilization







```
Dataset: PPG-1.csv, Sampling Rate: 125 Hz, Duration: 20 Minutes
Dataset: PPG-2.csv, Sampling Rate: 125 Hz, Duration: 20 Minutes
Dataset: PPG-3.csv, Sampling Rate: 100 Hz, Duration: 3 Minutes
Dataset: PPG-4.csv, Sampling Rate: 100 Hz, Duration: 210 Minutes
Dataset: PPG-6.csv, Sampling Rate: 128 Hz, Duration: 10 Minutes
Index(['Time', 'PPG'], dtype='object')




Dataset: PPG-1.csv, PPG Min: 0.0, PPG Max: 1.0
Dataset: PPG-2.csv, PPG Min: 0.110459433, PPG Max: 0.99315738
Dataset: PPG-3.csv, PPG Min: -126795.0, PPG Max: -125954.0
Dataset: PPG-4.csv, PPG Min: -235356.0, PPG Max: -199805.0
Dataset: PPG-6.csv, PPG Min: -87320.41406, PPG Max: -16220.49414
PPG-3.csv Corrected PPG Min: 0.0, Max: 1.0
PPG-4.csv Corrected PPG Min: 0.0, Max: 1.0
PPG-6.csv Corrected PPG Min: 0.0, Max: 1.0


Dataset: PPG-1.csv, PPG Min: 0.0, PPG Max: 1.0
Dataset: PPG-2.csv, PPG Min: 0.110459433, PPG Max: 0.99315738
Dataset: PPG-3.csv, PPG Min: -126795.0, PPG Max: -125954.0
Dataset: PPG-4.csv, PPG Min: -235356.0, PPG Max: -199805.0
Dataset: PPG-6.csv, PPG Min: -87320.41406, PPG Max: -16220.49414
Dataset: PPG-1.csv, Normalized PPG Min: 0.0, Normalized PPG Max: 1.0
Dataset: PPG-2.csv, Normalized PPG Min: 0.110459433, Normalized PPG Max:
0.99315738
Dataset: PPG-3.csv, Normalized PPG Min: 0.0, Normalized PPG Max: 1.0
Dataset: PPG-4.csv, Normalized PPG Min: 0.0, Normalized PPG Max: 1.0
Dataset: PPG-6.csv, Normalized PPG Min: 0.0, Normalized PPG Max: 1.0



Dataset: PPG-1.csv
  Mean Heart Rate: 61.13232181504336 BPM
  Mean Respiratory Rate: 18.990132479974346 breaths/min
  Mean Systolic Amplitude: 1.0 units
  Signal-to-Noise Ratio: 9.411501669981297
  Kurtosis: -0.8851487497780175
  Skewness: 0.3879060906037161
```

```
Dataset: PPG-2.csv
  Mean Heart Rate: 68.88778905736461 BPM
  Mean Respiratory Rate: 20.01427685082025 breaths/min
  Mean Systolic Amplitude: 0.882697947 units
  Signal-to-Noise Ratio: 8.808327585863015
  Kurtosis: -0.6783152094271059
  Skewness: 0.5740812697184955

Dataset: PPG-3.csv
  Mean Heart Rate: 85.09526354690458 BPM
  Mean Respiratory Rate: 21.384928716904277 breaths/min
  Mean Systolic Amplitude: 1.0 units
  Signal-to-Noise Ratio: 10.554724595643224
  Kurtosis: -0.37873239950696114
  Skewness: 0.08428115857350643

Dataset: PPG-4.csv
  Mean Heart Rate: 54.82754192542368 BPM
  Mean Respiratory Rate: 20.54200019288263 breaths/min
  Mean Systolic Amplitude: 1.0 units
  Signal-to-Noise Ratio: 4.32968243676336
  Kurtosis: -1.3656773703292737
  Skewness: -0.4308959085936372

Dataset: PPG-6.csv
  Mean Heart Rate: 70.46577781605222 BPM
  Mean Respiratory Rate: 18.82549285490769 breaths/min
  Mean Systolic Amplitude: 1.0 units
  Signal-to-Noise Ratio: 40.69655034803403
  Kurtosis: 0.6927502147428188
  Skewness: -1.219801173492364
------------------------------------------------------------
Dataset: PPG-1.csv
  Irregular Heart Rate: Yes
  Abnormal Waveform: Yes
------------------------------------------------------------
Dataset: PPG-2.csv
  Irregular Heart Rate: Yes
  Abnormal Waveform: Yes
------------------------------------------------------------
Dataset: PPG-3.csv
  Irregular Heart Rate: No
  Abnormal Waveform: Yes
------------------------------------------------------------
Dataset: PPG-4.csv
```

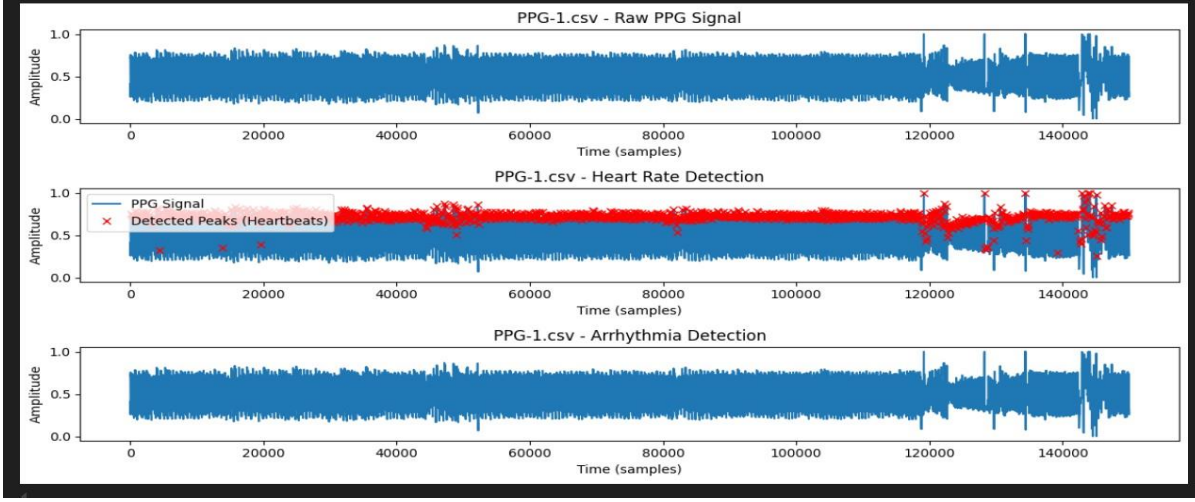
```
  Irregular Heart Rate: No
  Abnormal Waveform: Yes
--------------------------------------------------
Dataset: PPG-6.csv
  Irregular Heart Rate: No
  Abnormal Waveform: Yes


Dataset: PPG-1.csv, SNR: 6.34
Dataset: PPG-2.csv, SNR: 6.30
Dataset: PPG-3.csv, SNR: -856.14
Dataset: PPG-4.csv, SNR: -17.39
Dataset: PPG-6.csv, SNR: -1.71




Dataset: PPG-1.csv, Heart Rate Variability (HRV): 0.09 seconds
Dataset: PPG-2.csv, Heart Rate Variability (HRV): 0.21 seconds
Dataset: PPG-3.csv, Heart Rate Variability (HRV): 0.11 seconds
Dataset: PPG-4.csv, Heart Rate Variability (HRV): 0.27 seconds
Dataset: PPG-6.csv, Heart Rate Variability (HRV): 0.25 seconds
```

```
Dataset: PPG-1.csv
Mean Heart Rate: 61.13 BPM
Mean Respiratory Rate: 18.99 breaths/min
Mean Systolic Amplitude: 1.00 units
Heart Rate Variability (HRV): 0.09 seconds
Arrhythmia Detected: No
```



```
Dataset: PPG-2.csv
Mean Heart Rate: 68.89 BPM
Mean Respiratory Rate: 20.01 breaths/min
Mean Systolic Amplitude: 0.88 units
Heart Rate Variability (HRV): 0.21 seconds
Arrhythmia Detected: No
```