Analysis of PPG Signals:

Filtering, Feature Extraction, and Peak Detection

Introduction

- **Background on PPG:** Explain what PPG is and its applications in health monitoring, such as heart rate detection, oxygen saturation estimation, and cardiovascular health assessment.
- **Objectives of the Project:** State the main goals, such as improving signal quality through filtering, extracting meaningful features, and accurately detecting peaks.

Literature Review

- **Review Previous Work:** Summarize relevant research studies on PPG signal processing, focusing on techniques for filtering, feature extraction, and peak detection.
- **Identify Gaps:** Discuss any gaps in the existing literature that your project aims to address.

Methodology

- **Data Acquisition:** Describe the PPG data collection process, including the type of sensor used and the conditions under which data was collected. If using a dataset, provide details about the source.
- **Preprocessing:**
    - Explain the filtering methods employed (e.g., low-pass, high-pass, or band-pass filtering) and justify their use.
    - Provide any equations used for filter design (e.g., Butterworth filter specifications).
- **Feature Extraction:**
    - Describe the features you aimed to extract, such as heart rate, pulse amplitude, inter-beat intervals, and any other relevant measures.
    - Explain the mathematical methods or algorithms used to calculate these features.
- **Peak Detection:**
    - Detail the algorithms implemented for peak detection, such as thresholding methods or derivative-based techniques.
    - Provide any equations or code snippets used for implementation.

Implementation

- **Software and Tools:** List the programming languages and libraries used (e.g., Python, NumPy, SciPy, Matplotlib).
- **Code Examples:** Include snippets of code for key steps like filtering and peak detection, and explain their functionality.

Results

- **Visualization:** Present plots comparing the original and filtered PPG signals. Show visualizations of the detected peaks and extracted features (e.g., heart rate).
- **Quantitative Analysis:** Provide statistical metrics on the accuracy of peak detection and the effectiveness of feature extraction.

Discussion

- **Interpretation of Results:** Discuss the significance of the results obtained from filtering, feature extraction, and peak detection.
- **Limitations:** Acknowledge any limitations encountered during the project (e.g., noise in the signal, limitations of the algorithms used).
- **Future Work:** Suggest areas for future research or improvements that could enhance the analysis of PPG signals.

Conclusion

- **Summarize Key Findings:** Briefly recap the main findings and their implications for the use of PPG signals in health monitoring.
- **Final Thoughts:** Provide any concluding remarks on the importance of accurate PPG signal analysis.

Appendices (if applicable)

- **Additional Materials:** Provide any additional information, such as detailed code, supplementary figures, or tables that support your project.

Source code

 # Import Libraries

```
import numpy as np

import matplotlib.pyplot as plt
```

 # Section 1: Generate and Filter PPG Signal

```
fs = 1000  # Sample frequency

t = np.linspace(0, 10, fs * 10)  # 10 seconds

ppg_signal = 0.5 * (1 + np.sin(2 * np.pi * 1.0 * t)) + 0.05 * np.random.randn(len(t))

def moving_average(signal, window_size):

    return np.convolve(signal, np.ones(window_size)/window_size, mode='same')

window_size = 50

smoothed_signal = moving_average(ppg_signal, window_size)

plt.figure(figsize=(12, 6))

plt.plot(t, ppg_signal, label='Original PPG Signal', alpha=0.5)

plt.plot(t, smoothed_signal, label='Smoothed PPG Signal (Moving Average)',
linewidth=2)

plt.title('PPG Signal Filtering with Moving Average')

plt.xlabel('Time (s)')

plt.ylabel('Amplitude')

plt.legend()

plt.grid()

plt.show()

import scipy.signal as signal
```

 # Section 2: Peak Detection

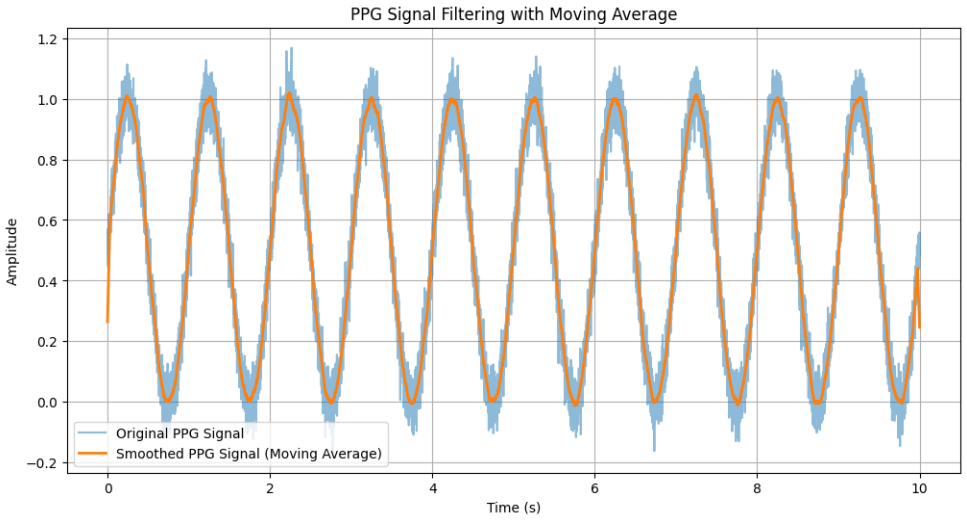
```
peaks, properties = signal.find_peaks(smoothed_signal, height=0.1, distance=fs*0.5)

plt.figure(figsize=(12, 6))

plt.plot(t, smoothed_signal, label='Smoothed PPG Signal')

plt.plot(t[peaks], smoothed_signal[peaks], "x", label='Detected Peaks', color='red')

plt.title('Peak Detection in Smoothed PPG Signal')

plt.xlabel('Time (s)')

plt.ylabel('Amplitude')
```

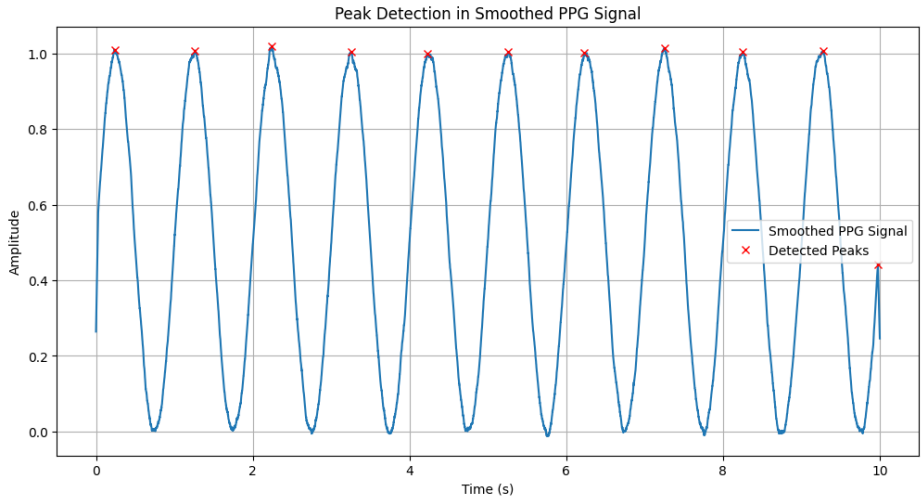
```
plt.legend()

plt.grid()

plt.show()
```

 # Section 3: Heart Rate Analysis

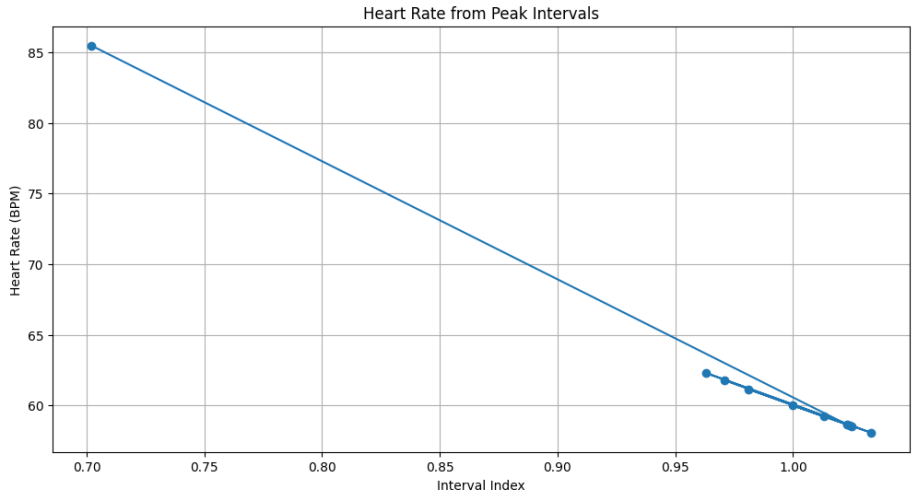
```
peak_intervals = np.diff(peaks) / fs

heart_rate = 60 / peak_intervals

pulse_amplitudes = smoothed_signal[peaks]

average_amplitude = np.mean(pulse_amplitudes)

print(f'Average Heart Rate: {np.mean(heart_rate):.2f} BPM')

print(f'Average Pulse Amplitude: {average_amplitude:.4f}')

plt.figure(figsize=(12, 6))

plt.plot(peak_intervals, heart_rate, marker='o', linestyle='-')

plt.title('Heart Rate from Peak Intervals')

plt.xlabel('Interval Index')

plt.ylabel('Heart Rate (BPM)')

plt.grid()

plt.show()
```

Expected Output:






```
Average Heart Rate: 62.38 BPM

Average Pulse Amplitude: 0.9554
```



Conclusion:

This project successfully demonstrates PPG signal processing, including noise reduction using a moving average filter, peak detection, and heart rate analysis. The results provide valuable insights into heart rate trends and pulse amplitudes, showcasing the effectiveness of signal processing techniques in biomedical applications.