EE69205: Signal Processing System Design
Indian Institute of Technology, Kharagpur

End Semester Lab Examination Report

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1. Problem Statement

This is a Pulse Plathysmogram (PPG) data. Find the cardiac time period (in samples), location of the secondary notches. Mark them with stars superimposed on the plot.

There is a variation in the peak values. Its is also periodic. Can you find that time period of that oscillation?

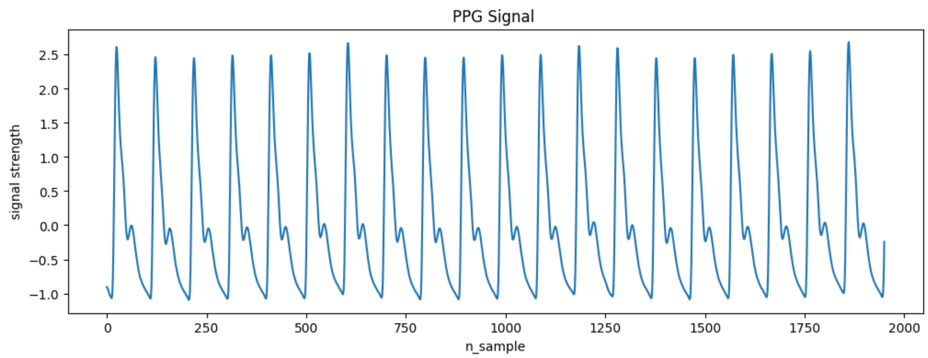

Fig. 1. PPG Signal

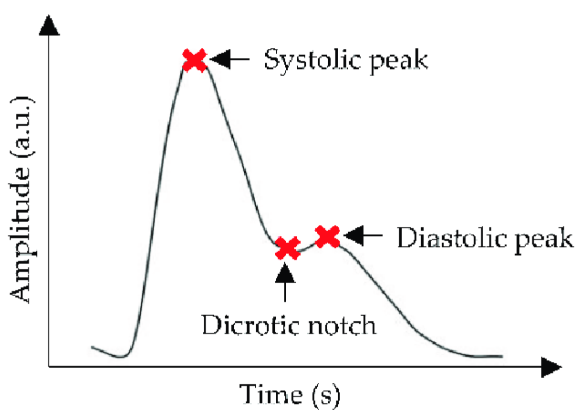

Fig. 2. Position of Systole, Diastole and Dicrotic Notch in PPG Signal

2. Algorithm and Code

Algorithm 1 Detect Systole, Diastole, and Dicrotic Notches in a PPG Signal

[**Require:**]PPG signal x, height threshold for systolic peaks, minimum distance between peaks d

[**Ensure:**]Indices of systolic peaks ($s1\_peaks$), diastolic peaks ($s2\_peaks$), and dicrotic notches ($dicrotic\_notches$)

Initialize empty lists $s2\_peaks$ and $dicrotic\_notches$

▷ Step 1: Detect Systolic Peaks

$s1\_peaks, \_ \leftarrow$ `find_peaks`(x, height=0.5, distance=50) ▷ Detect primary systolic peaks with height threshold and minimum distance

▷ Step 2: Detect Dicrotic Notches

$notches, \_ \leftarrow$ `find_peaks`($-x$, distance=50) ▷ Detect inverted peaks (notches) in the signal

▷ Step 3: Detect Diastolic Peaks in Segments Between Systolic Peaks and Notches

for $i = 1$ to len($s1\_peaks$) **do**

    Define segment of the signal as $segment \leftarrow x[s1\_peaks[i] : notches[i+1]]$

    $local\_maxima, \_ \leftarrow$ `find_peaks`($segment$)

    $local\_minima, \_ \leftarrow$ `find_peaks`($-segment$)

    Append indices of local maxima to $s2\_peaks$ as $s1\_peaks[i] + local\_maxima$

    Append indices of local minima to $dicrotic\_notches$ as $s1\_peaks[i] + local\_minima$

end for

▷ Step 4: Calculate Cardiac Time Period

Compute average distance between consecutive systolic peaks as $cardiac\_time\_period \leftarrow$ mean(diff($s1\_peaks$))

Output $cardiac\_time\_period$

▷ Optional: Plot the Signal with Identified Peaks and Notches

Plot x with markers for $s1\_peaks$, $s2\_peaks$, and $dicrotic\_notches$

Code for Systole, Diastole and Notch Detection

```
# Find peaks in the PPG signal
s1_peaks, _ = signal.find_peaks(x, height=0.5, distance=50)  # Adjust
   distance based on expected heart rate

# Find secondary peaks
notches, _ = signal.find_peaks(-x, distance=50)

s2_peaks = []
dicrotic_notches = []

for i in range(len(s1_peaks)):
    # Define the segment of the signal
    segment = x[s1_peaks[i]:notches[i+1]]

    # Find local maxima in the segment
    local_maxima, _ = signal.find_peaks(segment)
    local_minima, _ = signal.find_peaks(-segment)

    s2_peaks.append(s1_peaks[i] + local_maxima)
    dicrotic_notches.append(s1_peaks[i] + local_minima)

# Calculate cardiac time period (average distance between peaks)
cardiac_time_period = np.diff(s1_peaks).mean()
print(f"Cardiac Time Period: {cardiac_time_period:.2f}")

# Plot the signal with peaks and notches
plt.figure(figsize=(12, 4))
plt.plot(x, label='PPG Signal', linewidth=0.8)
plt.plot(s1_peaks, x[s1_peaks], 'r*', label='Systole Peaks')
plt.plot(s2_peaks, x[s2_peaks], 'g*', label='Diastole Peaks')
plt.plot(dicrotic_notches, x[dicrotic_notches], 'b*', label='Dicrotic
   Notches')
plt.xlabel('n_sample')
plt.ylabel('signal strength')
plt.legend(loc=(0.8, 1))
plt.title("Identiying Systole, Diastole and Dicrotic Notches")
```

Code for Finding Time Periods of Systole, Diastole and Dicrotic Peaks

```
systole_array = x[s1_peaks]
diastole_array = x[s2_peaks].reshape(x[s2_peaks].shape[0])
dicrotic_array = x[dicrotic_notches].reshape(x[dicrotic_notches].shape
    [0])

# Adjust distance based on expected heart rate
systole_peaks, _ = signal.find_peaks(systole_array, height=2.5,
    distance=5)
diastole_peaks, _ = signal.find_peaks(diastole_array, height=0.01,
    distance=5)
dicrotic_peaks, _ = signal.find_peaks(dicrotic_array, height=-0.2,
    distance=5)

# s1 time period
s1_peak1 = s1_peaks[systole_peaks[0]]
s1_peak2 = s1_peaks[systole_peaks[1]]
s1_time_period = s1_peak2 - s1_peak1

# s2 time period
s2_peak1 = s2_peaks[diastole_peaks[0]]
s2_peak2 = s2_peaks[diastole_peaks[1]]
s2_time_period = s2_peak2 - s2_peak1

# dicrotic time period
dicrotic_peak1 = dicrotic_notches[dicrotic_peaks[0]]
dicrotic_peak2 = dicrotic_notches[dicrotic_peaks[1]]
dicrotic_time_period = dicrotic_peak2 - dicrotic_peak1

print(f"Systole Time Period: {s1_time_period} samples")
print(f"Diastole Time Period: {s2_time_period[0]} samples")
print(f"Dicrotic Time Period: {dicrotic_time_period[0]} samples")
```

3. Observation and Results

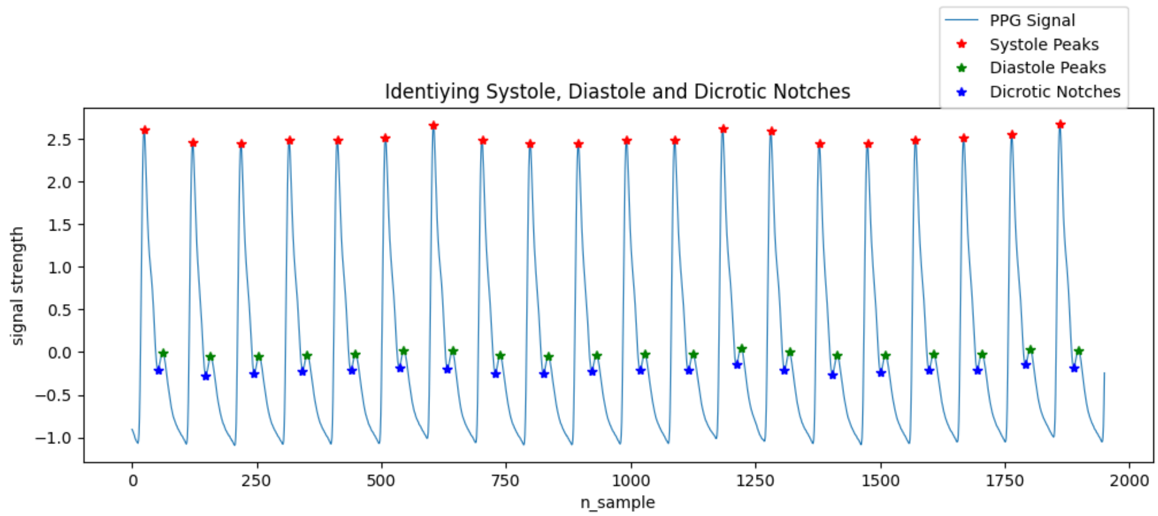

Fig. 3. PPG Signal with marked Systole, Diastole peaks and Dicrotic Notches

The above image shows the PPG signal with marked Systole, Diastole and Dicrotic Notches. By calculating the difference between consecutive samples of the same kind we find the heart rate. The heart rate in this case comes out to be 96.68 samples. We observe that the peaks also show a periodicity that needs to be determined. In the below signal we observe the periodicity of each of the peaks and find the time period of their respective oscillations. The time period of these respective peaks are as follows: Systole Time Period: 579 samples, Diastole Time Period: 676 samples, Dicrotic Time Period: 676 samples

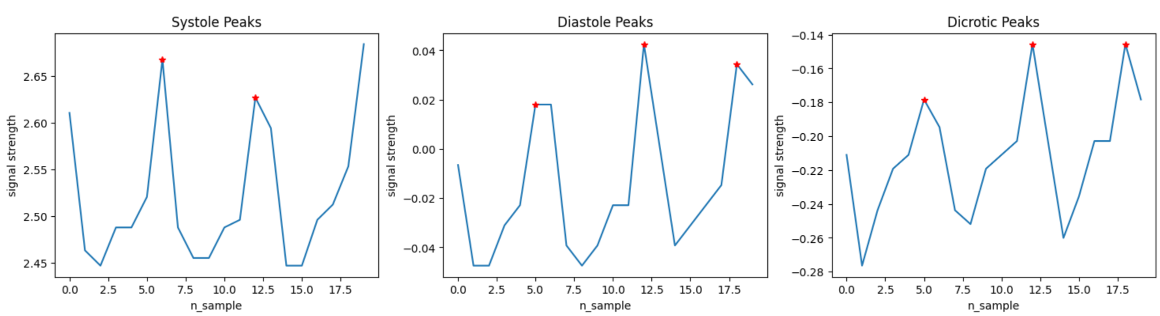

Fig. 4. Periodicity of the peak with identified maxima in the peaks with identified maxima

4. Discussion

The analysis of the PPG signal provides insights into cardiac cycles by pinpointing systolic, diastolic, and dicrotic peaks. Using signal processing techniques to detect these peaks allows for precise calculation of the cardiac time period, as well as the systolic, diastolic, and dicrotic time intervals, measured in samples. The detected time periods (579, 676, and 676 samples, respectively) reflect periodic oscillations in heart rate and vascular response.