Measuring heart rate from PPG signals

Overall idea

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Photoplethysmographic (PPG) signal is used in fitness watches to measure Heart Rate. Initially ECG was the only method to measure heart rate, but with advent of time new methods were introduced for the purpose. PPG signal is obtained from pulse oximeters. They take in consideration the amount of light (intensity) reflected by blood, giving information about the rate of flow of blood pumped by heart. The frequency of these signals is the cardiac rhythm and can be used to measure heart rate. However due to motion we can see noise being introduced in it. The main purpose of this project is to find the Heart Rate from given ppg signal.

First Approach

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The basic and foremost approach to this problem by us was to consider ppg signal to be pure. Hence we considered it to be free of motion noise and simply calculated the heart rate based on the prominent frequency in fft. Point taken into consideration were :

- Heart Rate can only have some feasible range of frequency
- We took it to be 0.5Hz to 2.5Hz

Then we found the peak in the given range and found heart rate according to sampling rate.

Drawbacks:

- Error was high.
- Motion artifacts not taken into consideration.
- Resolution in fft is less

Second Approach

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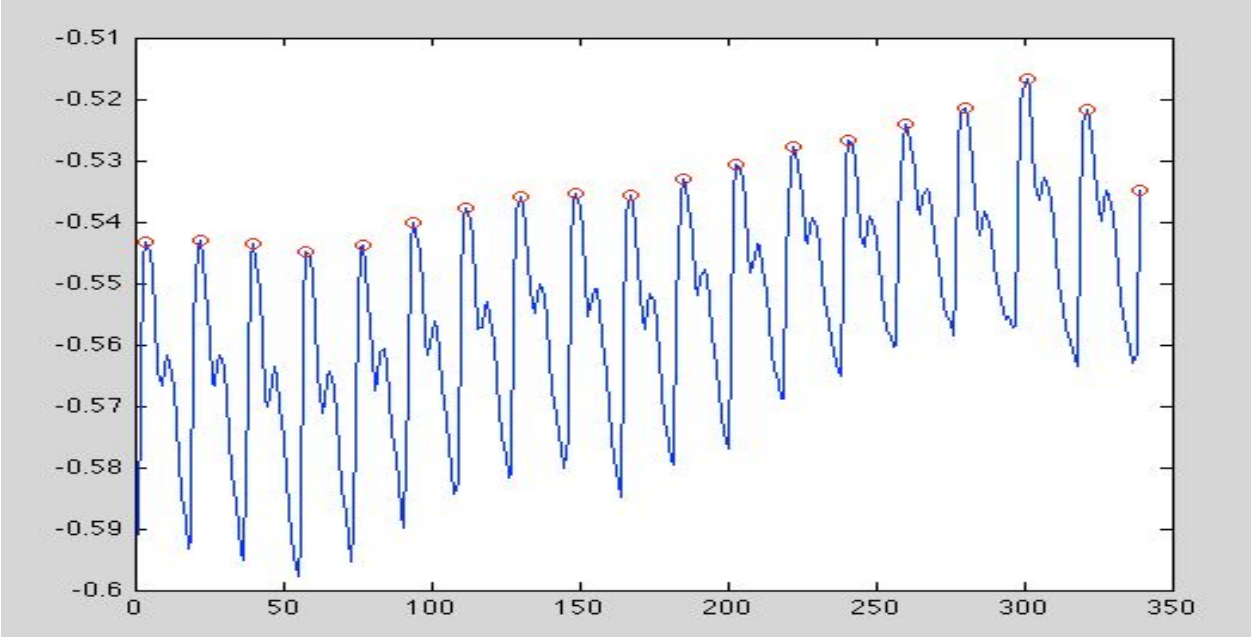

We considered ppg to be periodic. Removing noise is important. We started considering that noise would change the frequency, but we could use the average periodicity to find the bpm. Hence we used findPeaks to find the peaks in a given error range and found the BPM according to corresponding periodicity and sampling rate.

Third Approach

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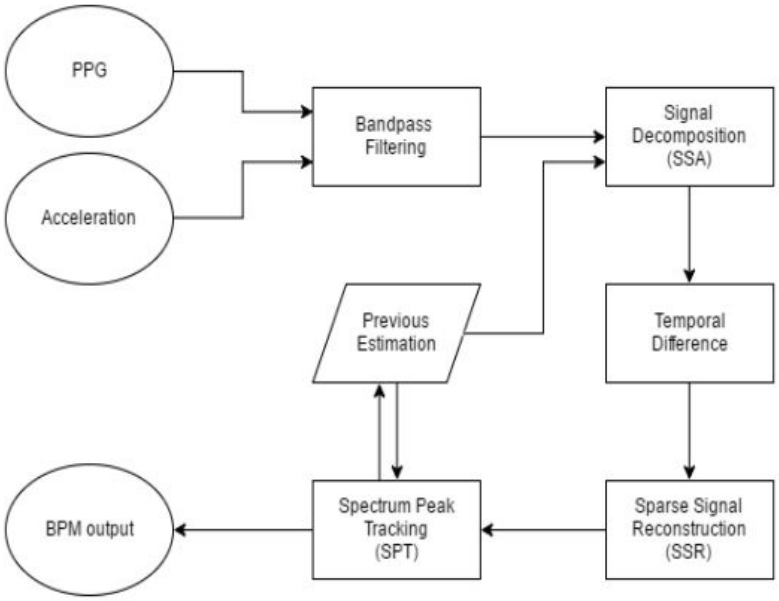
We referred to online research papers and articles regarding various methods to reduce noise in PPG signals and remove noise due to motion from them. We came across Wiener filter and TROIKA algorithm. We looked upon various implementations and looked for scope of betterment. We saw the time to compute was high and error was too much. Hence after implementing it we looked for various other methods for the same. Its flow is as shown below:

1. First do bandpass filtering to remove frequencies which can't possibly be heart rate.
2. Decompose the signal into various sub-signals and use temporal difference method to remove components corresponding to motion and noise from it.
3. Reconstruct the signal.

4. Spectrum Peak Tracking to find the Heart Rate Peaks.



Note: Here Previous estimation is used because heart rate can't change by a sudden value, hence it can be used to filter out unnecessary signal.

Fourth Approach

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We came across Adaptive Noise Cancellation method as an alternative to wiener filter. It follows least mean square and Recursive Least Square methods for filtering We looked upon its implementation. Then we came across JOSS. JOSS is similar to TROIKA in all the senses except instead of Temporal Difference, Spectral subtraction technique

is used. Also JOSS does operations in frequency domain compared to TROIKA which does it in time domain. Hence it is faster compared to TROIKA. JOSS does the following:

1. We construct a sparse signal using fft for given precision, which is taken to be of 1/30th of a second. We remove Motion's noise from it.
2. using temporal difference we remove the noise.
3. Then we reconstruct the signal and find the BPM for the given signal.

Fifth Approach

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We combined all the above techniques for the final output. Initially the heart rate is measured by using Periodogram, then ANC and then JOSS. This is also known as the SMART technique except a few changes. The order is in increasing order of time. We observed that SMART was too analogous, This was because of less resolution as we had to limit the time. Hence we used bilinear filter to smoothen the signal to get correct values. It follows the principle that there is no sudden change in heart rate.

Final Approach

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Time taken for all the above processes is very high. Although ANC and Periodogram takes less time but it also comes with less accuracy. But JOSS has higher accuracy values. Also we had came across a research paper on a simple filter called Wiener filter in the beginning. Although its accuracy was high but it did show abrupt behavior at places. Hence we combined all the above methods. We followed following steps:

1. First get a approx BPM using Wiener Filter method.
2. If the jump in adjacent BPM is more than 5, then we use JOSS for better approximation.
3. Finally we truncate the output to only first 125 values

WE DID REFER QUITE A LARGE NUMBER OF RESEARCH PAPERS. THEY ARE AVAILABLE HERE