DSAA Project

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Background

Fitness tracking is gaining massive popularity due to the advent of wearable devices that can track your vital signs. Heart rate monitoring is one such feature in many devices such as smart-watches and wristbands. The heart rate is estimated in real time

and can guide exercises to adjust their workload and training programs, which is especially useful in rehabilitation.

Most of the recording is done using photoplethysmographic (PPG) signals which are recorded from the wearer's wrist. The PPG signal is recorded using embedded pulse oximeters. A pulse oximeter records a signal by illuminating the skin with an LED and

measuring the intensity changes as the light reflects off the exercises during the Wearer's skin, forming a PPG signal. Each cycle of the PPG signal corresponds to a cardiac cycle, thus the heart rate can be estimated from the periodicity of the PPG Signal.

Abstract

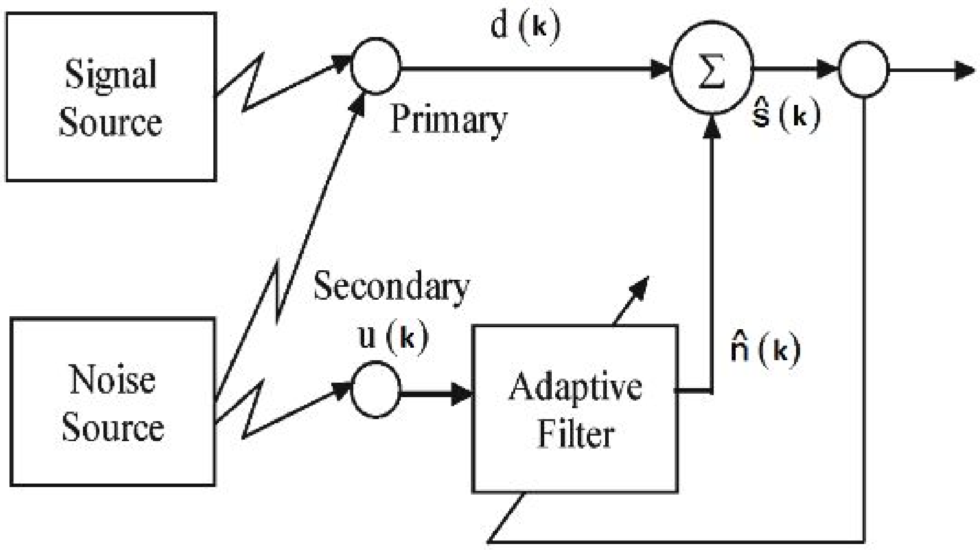
The heart rate (HR) is the number of times your heart beats per minute. For the average person this rate is between 60 and 100 beats per minute (BPM) when in rest. Monitoring the HR can give a person insights on their medical condition as well as their fitness level. When performing physical activities, monitoring the HR is useful since it can help the user keeping track of their training load. The goal of the project is to write software that can accurately monitor real-time HR with PPG sensors placed on the wrist.

The techniques being used for the purpose of HR calculation in this Project are Adaptive Noise Cancellation(ANC), TROIKA and JOSS. Studying over time has proved JOSS to be the better of the 3 technique.

WORKING

Though, JOSS has been found to be the better of the 2 techniques(ANC, JOSS), it still uses a lot of computing power which takes a lot of time. Therefore, both the methods were implemented in order to come to a more robust solution. An improved framework, in terms of computing power is presented. This framework combines multiple signal processing techniques and exploits general properties of PPG signals.The low computational power is used to track HR on the go and is very useful in giving efficient timely outputs.

ANC

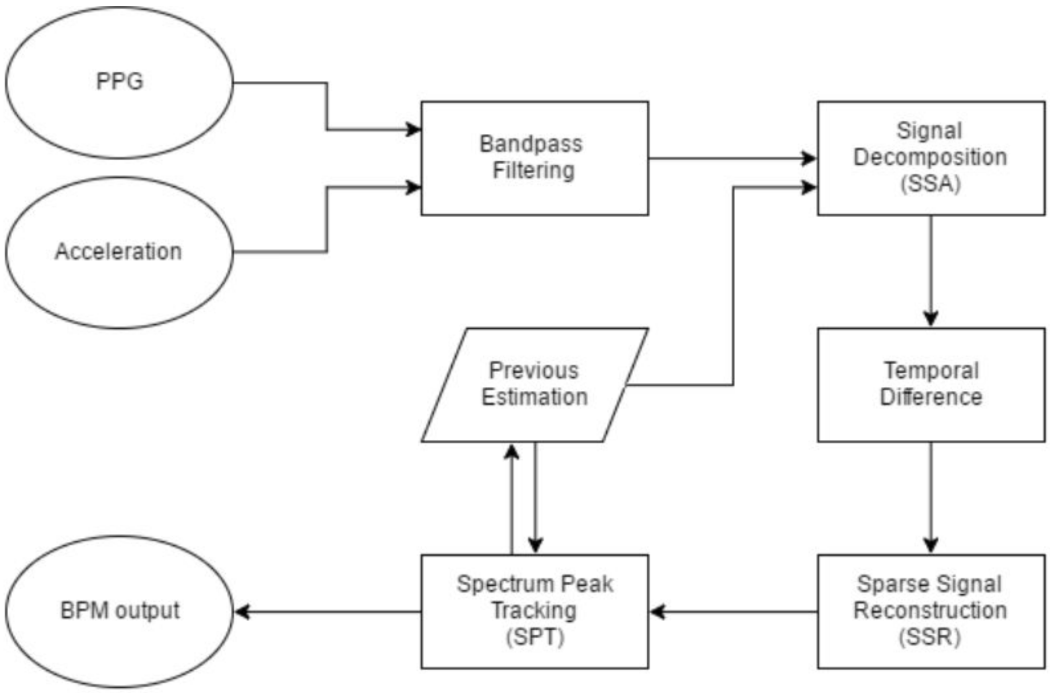


ANC is a form of noise cancellation. Unlike fixed filters, the parameters of adaptive filters are

adaptive. This means that they change according to the characteristics of the system. This is

advantageous as no prior knowledge of the signal or noise is needed for this method to work.

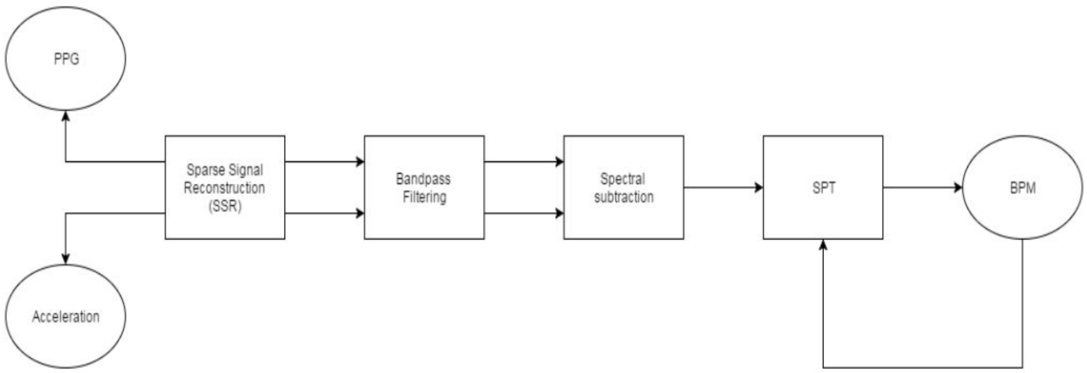
TROIKA



TROIKA is a framework that consists of three key parts: signal decomposition, Sparse Signal Reconstruction (SSR) and Spectral Peak tracking (SPT). TROIKA works with PPG signal and also uses acceleration data. Before the PPG signal goes into the signal decomposition state, it goes through a bandpass filter. This filter removes frequencies that cannot be associated with a humanly possible heart beats. The signal decomposition stage is used to denoise the PPG signal and remove motional artifacts. this is done by decomposing a single signal into multiple components. The components can then be analysed and interference can be removed. After that the signal is reconstructed

without those components. Before the signal goes through the SSR stage, it is temporally differentiated to remove MA components that correspond with aperiodic movements. The SSR stage gives a high resolution spectrum estimation of the signal, which makes the peak tracking easier. The SPT stage analyses the signal that is created by SSR and selects the spectral peaks that correspond with the heart beat. The project uses JOSS which is a framework built on top of TROIKA

JOSS



JOSS (JOint Sparse Spectrum reconstruction) is a framework built on top of TROIKA. It makes

use of SSR and SPT, just like TROIKA, but it differs in the technique used for MA removal.

TROIKA uses signal decomposition techniques to remove MA while JOSS uses spectral

Subtraction. First an accurate sparse spectrum of the PPG signal and acceleration

components are constructed using FOCUSS . Then the spectra are band-pass filtered to

remove unrealistic heart rates. The acceleration spectrum is then subtracted from the PPG

spectrum. This removes peaks corresponding to MA from the PPG spectrum. The result of this

is a cleansed spectrum used by SPT to produce a BPM output. This output is then used as

feedback for SPT to search in smaller intervals.

Quality of a PPG signal

To identify when a simple periodogram can be used to determine the HR for PPG signals, a parameter has to be found to identify whether the PPG signal has good quality. The goal is thus to find a criterion for which the error produced by simply using the periodogram is low.

For this purpose kurtosis has been used. It is a measurement for how peaked a signal is, and is

calculated using the kurtosis function used in Matlab.

The functions are tried in the order periodogram, then ANC and then JOSS based on the quality observed for the predicted heart rate.

Final Function

JOSS is a good solution for estimating the HR but it requires a lot of computing power. Therefore, for monitoring the HR throughout the day, the function gives an alternative framework. It combines multiple signal processing techniques by means of stages. In the first

stage a fast method of determining the HR is present, such as a simple periodogram. In the subsequent stages there are slower, but more accurate, signal processing techniques. If none

of the techniques within these stages are good enough to calculate decent result, the last stage is triggered. In the last stage, JOSS is used for computing the HR. The function determines which of these techniques to use based on the quality of the PPG signal and the

previously determined HR. This framework uses the robustness of a JOSS technique, while using less computing power whenever possible.

Refrences

TROIKA: A General Framework for Heart Rate Monitoring Using Wrist-Type Photoplethysmographic Signals During Intensive Physical Exercise

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PPG

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Heart rate monitoring from wrist-type photoplethysmographic (PPG) signals during intensive physical exercise

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SPO2

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