A FINGER-PULSE-BASED MOBILE HEALTH MONITOR

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Introduction

Continuous cardiovascular monitoring has many benefits.
- It helps in the diagnosis and treatment of a number of major diseases, like heart diseases
- For healthy individuals, cardiovascular monitoring can also let them know about their health status and take early treatment if symptoms of disease arise

Mobile Health Monitor System consists of
- Ring size Photoplethysmography (PPG) sensor which is small and can be worn for long time
- Cell Phone for implement the measurement algorithm and displaying the results
- Constraints of the system
  - Due to the compact size of the ring sensor, the PPG signal is more likely to suffer from noise such as motion artifacts which is due to relative movement of the sensor with respect to the skin and ambient light due to light in the surroundings
  - The computation power of cell phone is limited. Therefore it is desirable to have a signal processing algorithm of low complexity. These have motivated me doing this research

This project aims at designing an low-complexity yet robust signal processing algorithm for the detection of heart beat rate and breathing rate using the from the PPG signal.

The objectives of the project are to produce a smart and intelligent signal processing algorithm for the PPG signal. The algorithm should produce accurate measurement in heart beat rate and breathing rate while providing robust tracking in variation in heart beat rate and breathing rate. It should also be able to resistant to noise and has low computational complexity.

Photoplethysmograph (PPG)
- Ring sensor contains two LEDs and one receiver. PPG is the waveform measured by the receiver
- The periodic pulsatile expansion of the arterial wall produces an increase in path length, thus amount of light absorbed by the blood, causing periodic variation in PPG signal with frequency equal to heart beat rate
- A low frequency variation is present in the PPG signal that can be used to extract breathing related information

Wavelet Transform

Wavelet Transform is used as a time-frequency signal analysis tool. It is defined as

\[
T(a, b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t) \psi* \left( \frac{t - b}{a} \right) dt
\]

By varying the scale variable \(a\) and time location variable \(b\), we can obtain information about the frequency composition of the signal at different time. The Wavelet Function \(\psi(t)\) can be chosen to suit the purpose of the application. One way in choosing the wavelet that has similar shape as the signal to be analyzed. One example is the Gaussian First Wavelet use in the Heart Beat Rate application.
Heart Beat Rate
Two methods are in measuring heart beat rate is analyzed.

- **FFT**
  - The frequency with maximum magnitude in the frequency spectrum is taken as the breathing rate

- **Wavelet Transform**
  - **Gaussian First Wavelet** is used
  - Wavelet transform is computed at scale $2^2$ and $2^4$
  - Wavelet coefficients shows periodic maxima and minima
  - By searching for modulus maxima (maxima with respect to time location $b$) in the wavelet transform coefficients, we can find the location of the Y-points, thus calculate the heart beat rate

Below shows a comparison of the heart beat rate obtained from the Wavelet Algorithm, FFT algorithm compared to that from a commercial pulse oximeter (Nonin Pusle Oximeter).

The heart beat rate measured by the Wavelet transform shows more robust and closer tracking with that from the Nonin Pusle Oximeter. In fact, the Wavelet Transform algorithm provide measurement of accurate heart beat rate.

Breathing Rate

- **Complex Morlet Wavelet** with centre frequency 1 Hz is used for breathing rate measurement.
- **2 bands** with higher magnitude in the scalogram, one from heart beat band the other breathing band respectively
- As the breathing band is of lower magnitude, it is easily obscured by low frequency noise
- “Secondary Wavelet Feature Decoupling” is employed to solve the problem
  - The ridge (locus of scale $a$ with maximum magnitude) is located and **“Ridge Amplitude Perturbations”**(RAP) signal is obtained
  - Wavelet Transform is performed on the RAP signal. A clearer breathing band can be observed
The Breathing Rate can be determined from the phase signal of the ridge in the RAP signal. The Phase signal shows periodic variation between \( \pi \) and \(-\pi\).

A drop of \( 0.9 \times 2\pi \) in phase represents a breath. Breathing rate can be calculated by counting the number of drops in the time period.

Fig 7 shows the breathing rate measured using the Wavelet Transform Algorithm with the subject breathing at a constant rate of 23 breaths per second. The measured breathing rate vary between 22 to 25 breaths per minute, which is pretty close to the breathing rate claimed by the subject.

**Conclusion**

Algorithm using wavelet transform in measuring heart beat rate and breathing rate from PPG signal are designed and studied. It was shown that accurate measurement in Heart Beat Rate can be obtained through the Wavelet Transform algorithm. It was also shown that it is possible to measure breathing rate from PPG signal. The future of the use of mobile health monitoring system comprising of ring PPG sensor and mobile phone in continuous cardiovascular monitoring is promising.