Intelligent Health Monitoring Using Mobile Phones

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**Project Code:** MWH1-08

### Introduction

**Motivation**
Cardiovascular disease and sleep apnea are major concerns of citizens living in urban cities like Hong Kong. Cardiovascular disease has been the second major cause of death for forty years in Hong Kong. In addition, patients of sleep apnea syndrome suffer from insomnia and deterioration of sleep quality. Continuous monitoring in cardio condition and sleep quality helps the citizens to find out their potential health problems.

Plethysmography (PPG) is a robust technology that provides simple and low-cost method to determine health indicators including heart rate and oxygen saturation (SpO2). With high penetration rate of the mobile phone and the increasingly portable biosensors, continuous health monitoring system using PPG becomes possible for personal use.

**Aim and Objectives**
The aim of our project is to develop a biosensor-based health monitoring application that works with multiple commercial biosensors and multiple mobile phones. The program implements different mathematical models to obtain biomedical data such as heart rate (bpm), breathing rate and information about obstructive sleep apnea. We aim to achieve simple and fairly accurate signal processing models which are suitable for mobile phones with limited computational power.

### Important Features

- Supports two commercial biosensors
  - Noise-free ELMO Bridge Chip
  - Chip-a Pulse Oximeter Module

- Breathing rate determination
- OSA determination
- Supports different brands of mobile phone
- Matlab, Java, Eclips, and Nokia

### Methodology

**PPG signal**
PPG signal is a type of plethysmography which is obtained optically. Using an LED that shines on the finger, the PPG signal can be obtained by measuring the reflected or transmitted light from the LED.

**Heart rate determination**

- **Running Average Method**
  - Define two average function with different window size
  - \( y(n) \): low-pass signal, window size 0.4s
  - \( y(n) \): Time-varying zero line, window size 3s
  - To get the period of complete cardiac cycle
  - Determine the maximum point by the condition
    - \( y(n) > y(n+1) > y(n+2) \)
    - \( y(n) > y(n-1) > y(n-2) \)
  - Calculate the heartbeat rate by the following:
    \[ HR = \frac{60}{T} \times \text{time duration between successive max points} \]

**Breathing rate determination**

- Fast Fourier Transform Method
  - Take the FFT of the PPG signal
  - The peak in the range of below 0.1Hz represents the breathing rate

**OSA determination**

- OSA is associated with periodic fluctuation of the heartbeat rate and the SpO2 (oxygen saturation rate)
- Peak occurs between 0.02Hz to 0.05Hz of the frequency spectrum

### Results

**Graphical User Interface**

- General Mode
- Simple Mode
- DSA Mode

### Evaluation

**PPG Simulation**
- To test the accuracy of heartbeat rate and breathing rate calculation algorithms

**Heart Rate Comparison**
- Compare the calculated heartbeat rate value with counting the wrist pulse in 5 minutes
- The percentage error with two commercial oximeters is small

**Average calculated HR**

<table>
<thead>
<tr>
<th>Device</th>
<th>Average HR (bpm)</th>
<th>Average HR by counting wrist pulse (bpm)</th>
<th>Percentage Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise-free ELMO</td>
<td>72.5 ± 10</td>
<td>79 ± 10</td>
<td>7%</td>
</tr>
<tr>
<td>Chip-a Oximeter</td>
<td>70 ± 10</td>
<td>71.5 ± 10</td>
<td>1.25%</td>
</tr>
</tbody>
</table>

**OSA Simulation**
- To test the performance of OSA-determination algorithm
- Use the sample OSA ECG data and normal ECG data from PhysioNet
- The OSA ECG data shown a peak between 0.021 to 0.05Hz while the normal ECG data does not