Demo Abstract: HeartSense – Estimating Blood Pressure and ECG from Photoplethysmograph using Smart Phones

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Abstract

ABSTRACT

Regular monitoring of certain vital parameters like heart-rate (HR), blood pressure (BP), Electrocardiogram (ECG) are the basic needs for elderly people and patients with chronic diseases residing at home. In this demo, authors would like to demonstrate the possibility of estimating BP levels and certain ECG parameters using the PPG signals captured from smart phones. The work includes mainly three components – (i) robust PPG signal acquisition, (ii) estimation of BP levels (low, medium, high) from PPG signals and (iii) estimation of PR, RR, QRS and QT intervals of ECG parameters from PPG signals. Initially certain time domain features are extracted from PPG, which are used to create training models for various BP levels and ECG parameters. The approach is tested on two benchmark hospital datasets from (i) University of Queensland and (ii) Capnobase TBME RR dataset and one dataset captured from smart phones. Results indicate that the estimation accuracy is above 75% and sometimes above 95% if the height, weight and age information are considered.

Categories and Subject Descriptors

G.4 [Application Software]: Robust System Deployment; H.1.2 [Smart phone based health care Systems]: Wellness Measurement; G.3 [System Implementation]: Robust realization - Fast Fourier transforms (FFT)

General Terms

Keywords
Heart rate, photoplethysmography (PPG), blood pressure (BP), electroencephalogram (EEG), wellness, smartphone based system

1. INTRODUCTION

In recent days, the preventive healthcare is a major focus especially with the growth of elderly population [1]. Initial screening with a low cost solution using a simple and portable device is the aim for such healthcare. Smart Phone based health care enables the detection of heart rate using reflective photoplethysmography (PPG). Apart from using the standard blood pressure measuring device, few works have been done on estimation of the BP using multiple mobile phone sensors or attaching an extra hardware to the smart phone [2], [3]. However, these solutions cannot be used in daily manner by individual patients at home. There have been solutions for measuring ECG with smart phones [4] with the usage of specialized external sensors.

The heart function and the structure of the blood arteries and veins majorly determine the blood flow in human body [5]. Hence we investigate the possibility of estimating BP levels and certain ECG parameters from PPG signals.

2. PPG DATA CAPTURE

In a smart phone the PPG signals are captured by placing the tip of the finger on top of the camera with the flash in “ON” mode. During this time certain noisy effects are observed in PPG signals due to improper placement of finger and motion artifacts. Moreover, variation of skin color between subjects affects the PPG signal. Hence there is a need for detecting consistent and clean portion in the PPG signal followed by feature extraction [6]. We perform the signal processing in hue (H), saturation (S) and value (V) domain and use the finite state approach as discussed in [7] to remove the noisy PPG signals. Frequency domain analysis on overlapped window is performed to derive the heart-rate. Table 1 gives the comparison of the accuracy of heart-rate detection with respect to the previous work. The clean PPG signal is used for feature extraction.

Table 1: Precision, Recall, F-Score and percentage (%) improvement in computation of HR for all the methods as compared to [7]

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Precision</th>
<th>Recall</th>
<th>F-Score</th>
<th>% Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method in [7]</td>
<td>0.81</td>
<td>0.42</td>
<td>0.55</td>
<td>-</td>
</tr>
<tr>
<td>Proposed Method</td>
<td>0.92</td>
<td>0.81</td>
<td>0.87</td>
<td>58</td>
</tr>
</tbody>
</table>
3. PPG FEATURE EXTRACTION
The feature extraction of PPG signal is mostly based on [6]. Figure 1 shows the magnified PPG signal for two cycles. Initially, the Systolic Peak (Tsn, Asn), the Valley Point (Tvn, Avn) and the Dicrotic Notch (Tdn, Adn) points of every cycle of the PPG signal are computed. Later fourteen features are computed from these. Due to space limitations the details of the features are not included in this paper. These features along with the height, weight and age information from individuals are used for training the models for BP and ECG parameters.

![Figure 1. PPG Signal for feature extraction](image1)

Figure 2: A complete cycle of ECG signal (source: Wikipedia)

4. ESTIMATION OF BP LEVELS
The diastolic and systolic BP levels are divided into various bins to indicate very low, low, normal, high and very high. The actual values of BP are mapped to one of these bins as ground truth and used for training linear regression and support vector machine (SVM). The ground truth BP data is captured using ETCOMM Portable PC ECG Monitor device. The ground truth data for ECG is captured using ETCOMM Portable PC ECG Monitor device. Similar analysis is done on the PPG signals captured from mobile device. The ground truth data for ECG is captured using ETCOMM Portable PC ECG Monitor device. The estimation accuracy of ECG parameters is above 85%.

Table 2: Comparison of accuracy (%) in estimating BP parameters using smart phone captured data.

<table>
<thead>
<tr>
<th>Method</th>
<th>Linear Regression</th>
<th>SVM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pd</td>
<td>Ps</td>
</tr>
<tr>
<td>14 features</td>
<td>80.3</td>
<td>82.1</td>
</tr>
<tr>
<td>17 features</td>
<td>99.7</td>
<td>98.7</td>
</tr>
</tbody>
</table>

5. ESTIMATION OF ECG PARAMETERS
A sample cycle of PPG waveform is shown in Figure 2. The ECG time interval parameters PR, and QT intervals are divided into 3 bins, RR in 4 bins and QRS interval is divided in 2 bins. A part of the PPG features are implemented from [6] and few new features are added. The PPG features are used to create training models for adaptive neural network (ANN) and SVM using the ground truth ECG parameters. The results for the Capnobase dataset are shown in Table 3.

![Figure 2: A complete cycle of ECG signal](image2)

Table 3: Accuracy (%) in estimating ECG parameters for Capnobase dataset [9]

<table>
<thead>
<tr>
<th>ECG param</th>
<th>With ANN (%)</th>
<th>With SVM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR</td>
<td>88.5</td>
<td>92.3</td>
</tr>
<tr>
<td>RR</td>
<td>94.9</td>
<td>96.6</td>
</tr>
<tr>
<td>QRS</td>
<td>84.1</td>
<td>84.9</td>
</tr>
<tr>
<td>QT</td>
<td>91.1</td>
<td>94.6</td>
</tr>
</tbody>
</table>

Table 4: Comparison of accuracy (%) in estimating BP parameters using smart phone captured data.

References:

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