Finger Blood Flow Monitoring Using Smart Phones

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ABSTRACT

The use of smart phones in healthcare applications is growing steadily. The inbuilt sensors are used to estimate the value of physiological data from human body. With progressive innovation, smart phone based medical applications will continue to be developed at an exponential rate. In this paper, we show that a smart phone can be used to monitor the blood flow in finger, based on the pulse height obtained from the fingertips. This is achieved by using the camera lens and the flash light of the smart phone. The height of the pulse rises along with the surrounding temperature indicating that the blood flow increases when the temperature becomes warmer. This study shows that there is a potential to monitor regulation of body temperature using smart phone.

Keywords

Finger blood flow, Mobile health, Smart phone, Finger pulse

1. INTRODUCTION

The latest generation of smart phones has become an essential commodity due to their variety of sensors, powerful computing capability, high memory capacity, and open source operating systems that encourage application development. Such a phone facilitates the use of ubiquitous health monitoring other than voice and data usage [7], [9].

Many mobile healthcare applications have been developed to monitor the physiological parameters such as heart rate, blood pressure [3], Electrocardiogram (ECG) [8] and oxygen saturation [12]. Another important parameter to be monitored is the blood flow and thermoregulation of the body.

The study of temperature effect on finger blood flow has been conducted by Wenger et al. [13] and Catherine O'Brien et al. [10]. The blood flow was measured with electro capacitance plethysmography and laser-Doppler respectively.

We hereby propose a way to measure the blood flow in finger affected by the surrounding temperature using a noninvasive method. The finger pulse is recorded by implementing photoplethysmography technology in smart phones as described by Banitsas et al.[1] and Jonathan et al. [6]. We examine whether the finger pulse varies with the temperature and the consistency of the variation.

2. EXPERIMENT TO MEASURE PULSE HEIGHT

2.1 Data Collection

The finger pulse is recorded using Nexus 4 (Google Inc.) smart phone. The left index finger is placed over the camera lens and the flash light. By positioning the phone as shown in Figure 1 , the phone is pressed down on the finger to have a fixed pressure and reduce any motion artifacts. The subjects are instructed to keep the finger still in this position. The pulse signal is recorded using the phone's camera at a sampling rate of 24 frames per second.

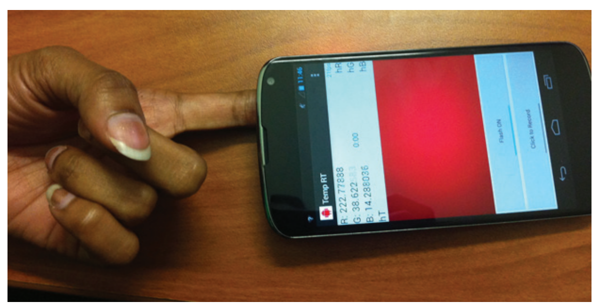

Figure 1: Experimental setup: The phone is placed over the index finger covering the camera and the flash light with a fix amount of pressure.

The subjects are asked to immerse their left hand in 95°F water. After 1 minute immersion, the subjects withdraw their hand, and the finger pulse is recorded for 5 seconds with the flash light on. The water temperature is then increased by 1°F and the subjects are asked to immerse their hand again. This procedure is repeated for each water temperature in the range of 95°F to 104°F.

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2.2 Pulse Detection and Height Calculation

Every heart beat sends a pulse wave to the fingertips. Each wave causes a flicker in the video frame. This series of flickering creates the pulse signals. The pixels in the first quadrant of the recorded video frame are taken into consideration as the pulse fluctuation is predominant in this region [3]. The pixels from each frame are extracted into Red, Green and Blue signals. The average value of each RGB component is computed to obtain the pulse.

Peak detection algorithm [11] was applied on the RGB signals to find the peaks and valleys. The algorithm uses a peak function for each sample in the signals defined as the mean of the maximum values between the left and right set of neighboring points for each sample. Further, based on the calculated mean and standard deviation for each of the peak function values, the local peaks or valleys were filtered. These local peaks and valleys are illustrated in Figure 2.

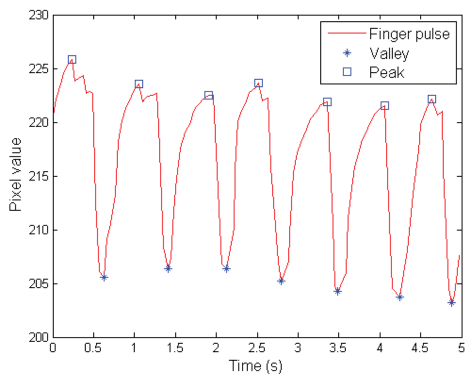

Figure 2: Example of red component in a pulse signal with its peaks and valleys obtained from the peak detection algorithm.

The average height of the pulse is then calculated by using the following equation:

$$\textit{Average height} = \textit{Average of peaks} - \textit{Average of valleys} \quad (1)$$

The total height of the pulse is determined as:

$$\textit{Total height} = \textit{Average height of Red signal} \times \textit{Average height of Green signal} \times \textit{Average height of Blue signal} \quad (2)$$

3. RESULTS

The total height for the water temperature range (95°F to 104°F) is plotted as an example for one individual in Figure 3. As the water temperature increases, the total height of the pulse increases exponentially. The results correlate with the outcomes presented by Barcroft [2] and Freeman [4]. Both the papers have demonstrated the effect of temperature change on the rate of blood flow and temperature in hand.

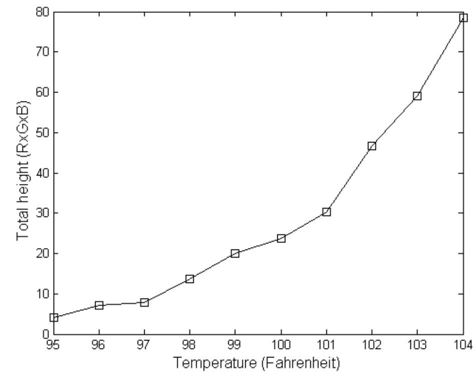

Figure 3: Example of total pulse height estimated from the finger pulse for each water temperature ranging from 95°F to 104°F.

4. DISCUSSION

4.1 Vasodilation

Vasodilation is widening of muscle around the walls of the blood vessels to expand the diameter of the blood vessel [5]. Vasodilation increases the blood flow and radiates excess heat from the body. When the body is exposed to heat, body temperature rises. Skin warmth receptors and blood convey these changes to the hypothalamic thermostat. The thermostat inhibits the activity of the sympathetic nervous system, thus causing vasodilation [5].

Warming of the hand causes vasodilation in the area being warmed. When the hand is immersed in hot water, the blood vessels expand, increasing the blood flow of the index finger. During a systolic pulse, the fingertips are filled with more blood cells, absorbing more flash light and leading to low pixel value. Likewise, during a diastolic pulse, less flash light is absorbed leading to high pixel value. This change of pixel values can be seen in Figure 2 which gives the measure of an individual's heartbeat. This waveform also gives the height of the pulse which corresponds to the blood vessel dilation. As the water temperature increases, the pulse height grows due to the capillaries expansion in the hand.

4.2 Consistency

The experiment was conducted thrice for each subject to analyze the consistency of the measurement. This is important to make sure that the height calculated from the pulse signals is in a certain constant range for each water temperature. An example of the measurement is displayed in Figure 4 where a quadratic curve is used to fit the data at each temperature value.

Each time the blood flows to the fingertips, the amount of blood cells in the fingertips varies. As the amount of blood cells changes, the amount of light absorbed and reflected also changes. This results in the variation of height for each measurement when the hand is immersed in the same water temperature. However, the value of the height appears in close proximity for every measurement.

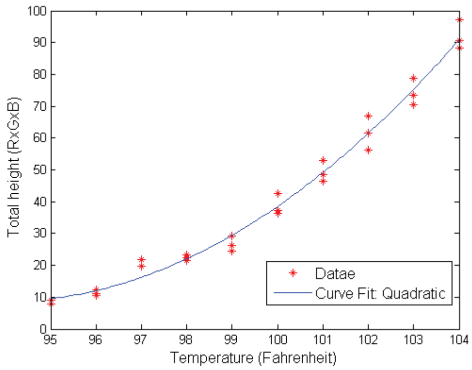

Figure 4: The measurements taken thrice for each water temperature are found to be in close proximity. The quadratic curve fitting shows that the height increases exponentially with the water temperature.

4.3 Finger Pressure on the Camera Lens

While measuring pulse using the smart phone, the pressure applied by the finger to cover the camera lens and flash light should not vary. If there is no pressure applied, the flash light is not covered fully, causing the light to scatter out instead of channeling into the finger. This produces a weak pulse with inconsistent height. If optimal pressure is applied to ensure the flash light is completely covered, coherent waveform is obtained where the pulses can be identified with constant height. As more pressure is applied, the pulse signal becomes sharper and the height increases. If the finger is pressed with full force over the camera, the blood flow to the fingertips is prevented. Consequently, there is no pulse recorded. Hence, pressure of the finger plays an essential role to obtain a clear plot and consistent height. The setup shown in Figure 1 is recommended for the same.

5. CONCLUSION AND FUTURE WORK

The application of blood flow monitoring using a smart phone gives an opportunity to measure another vital sign of the body i.e. temperature. In this work, we have utilized the mobile sensor (camera) to collect and process the physiological data. The developed application takes less than one second to process the pulse signal and display the total height. The preliminary results show that the smart phone cameras have the potential to monitor the vasodilation of the blood vessels.

Further study has to carried out to test the body temperature, thermoregulation and fever. This can help a person to monitor their homeostatic regulation.

6. ACKNOWLEDGEMENT

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