Determination of SpO$_2$ and Heart-rate using Smart-phone Camera

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Abstract—**Cardiovascular diseases are emerging as the leading cause of death worldwide. Preventive cardiology appears to be the most promising approach to tackle this problem. The greatest important component of effective preventive cardiology is to collect and monitor health data over an extended period of time. This can only be achieved with a non-invasive, very easy to use and widely available data collection process. The mobile phones with multiple inbuilt sensors can be used to design and develop applications to collect different biomedical signals. In this paper, we propose to use a mobile phone's camera to estimate two vital cardiovascular parameters, namely, pulse oximeter (SpO$_2$) level and heart-rate. This is achieved by using the phone's ability to record and detect variations in colour signals in a fingertip placed in contact with its optical sensor, i.e. camera. The accuracy of this application is confirmed by comparing the results obtained to that of standard pulse oximeters available in the market.**

Keywords—*cardiovascular diseases, preventive cardiology, pulse oximeter, mobile phone sensors*

I. INTRODUCTION

The amount of oxygen saturation (SpO$_2$) in the blood is a very important parameter for detection and prevention of cardiovascular disease. Haemoglobin is an essential component of blood; however it has very low solubility in it. To induce solubility, oxygen binds with it to form oxyhaemoglobin. Hence, we define a parameter called SpO$_2$ which is the ratio of the oxyhaemoglobin present in blood to the total haemoglobin content of the blood. SpO$_2$ levels are a measure of physical well-being. Normal SpO$_2$ levels are considered to lie in the range of 95-99. If the level is below 90 percent, it is considered low, resulting in conditions like hypoxemia. Blood oxygen levels below 80 percent may compromise organ function, such as the brain and heart, and should be promptly addressed. There is a need for low-cost physiological monitoring solutions that are easy to use, accurate, and can be used in the home or ambulatory settings. Smart phones are becoming more popular, more powerful and have a variety of sensors available to capture information from the outside world, process the data in real-time, and transfer information remotely using wireless communications. Extensive research has been conducted to monitor various physiological parameters without any need of additional hardware. These factors make smart phones an ideal choice and their potential has been explored for many medical telemonitoring applications.

Optical video monitoring of the skin with a digital camera and an external flashlight can be used to extract information related to the subtle color changes caused by cardiac signal as the blood flows in and out. The rate at which this colour change occurs can be used to determine heart rate of the person. Numerous applications exist on the Android market to calculate heart rate through optical recordings. But none of them manage to extract the SpO$_2$ level of the flowing blood. In this paper, we present the detail design of an application for recording SpO$_2$ level along with heart-rate. The results were also verified with standard equipment.

II. ALGORITHM

Pulse oximetry is a method used to determine the SpO$_2$ level of the blood. A small device that clips to the body (typically a finger),called a pulse oximeter, produces two different wavelength of lights which pass through the finger. Light which is not absorbed by the tissue is measured by a photo detector. Pulse oximetry is based on the principle that pulsatile blood absorbance of IR or red light changes with regard to degree of oxygenation. The signal at the receiver is divided into two parts: the AC component which is due to the pulsatile arterial blood and the DC component which is due to tissue background, venous blood and constant part of arterial blood flow. The DC component is subtracted while the AC component is amplified. The DC and AC parts can be used to calculate the SpO$_2$ level in the blood [1] as given by the formula (1):

$$SpO_2 = A - B\frac{AC_{RED}/DC_{RED}}{AC_{BLUE}/DC_{BLUE}} \quad (1)$$

Where, *A* and *B* are parameters that can be obtained by matching the SpO$_2$ graph obtained here with a the graph that is obtained by a standard pulse oximeter. In our case, after matching we found the values to be 100 and 5 respectively.

Another important parameter than can be obtained here is the heartbeat of the user. Periodic fluctuations in the received DC light on the receiver can be used very easily to estimate the heartbeat. Each heartbeat corresponds to an increase in brightness (red DC level) following a period of reduced brightness. If the number of peaks of DC light in a specific period of sampling is known, we can use this as per formula (2):

$$Heartrate = (No\ of\ peaks\ in\ DC\ Red\ Level\ in\ a\ sampling\ period\ *60\ /\ Sampling\ period) \quad (2)$$

The main challenge is to implement these algorithms using only a smart phone.

III.   IMPLEMENTATION

In commercial pulse oximetry, receivers look for the amount of absorption in red and infrared light [4]. However, to do away with the need for a separate infra red light source, blue light can be used as substitute. This is possible because results obtained with blue light emulate those obtained with infra-red light. For the implementation of this algorithm, the setup consists of a standard smartphone running Android 4.0.2 The device has a 1Ghz processor and came with a 5MP camera with flash and HD video recording capabilities. The code for the application was written in the Eclipse IDE for Java Development using the ADT (Android Developer Tools) plug-in. A source of white light containing active blue and red light components is pointed at the lens and the finger is placed in between. This light reaches the camera lens after passing through the finger and forms an image there. These images can then be processed for extracting information about the SpO_2 level. Now, we discuss the different steps involved for calculating SpO_2 in detail.

A. First Step

A representative setup for recording SpO_2 using phone camera is shown in Fig. 1. The first step of the algorithm involves the recording of a small video clip of around 20 seconds. Around 20 second is essential for the calculated values to stabilize. The user has to keep his index finger on the lens (palmar side towards from the lens) for the duration the video is to be recorded. For this particular implementation of the algorithm to work, white light has to pass through the finger and then be received by the phone's camera lens. This can be achieved by having a small source of white light (a different phone's flash or a torch with a white LED). After placing the finger on the lens, the user has to make sure that the image produced on the screen is sufficiently bright He then presses the *Start* button to start recording the clip.

In subsequent updates to this app, we'll be including a mechanism to check the image quality before allowing the user
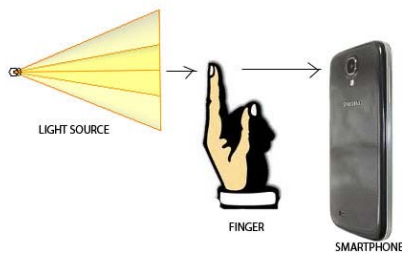

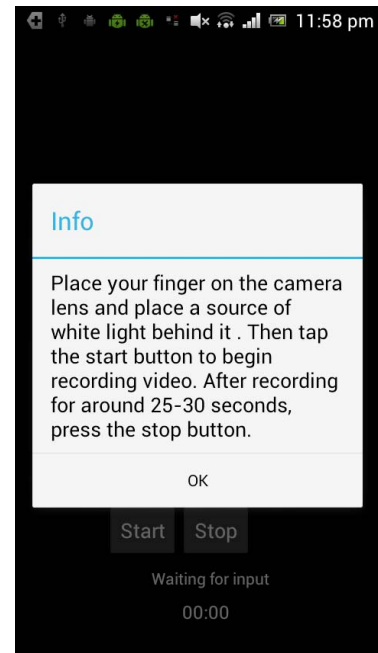Figure 1. A representative setup for recording SpO_2 using phone camera.

Figure 2. Startup screen of the SpO2 recording application

to record the clip. Fig. 2 shows the startup screen of the application.

B. Second Step

When around 20 seconds have passed, the user presses the *Stop* button. The pressing of this button stores the recorded video in the smart-phone's memory card. Once this happens, a new screen is launched in the app. The first 600 frames from the clip (corresponding to around 20 seconds of video) are extracted.

C. Third Step

After the extraction of the frames, they are parsed into an image holder where they were processed one by one. Each
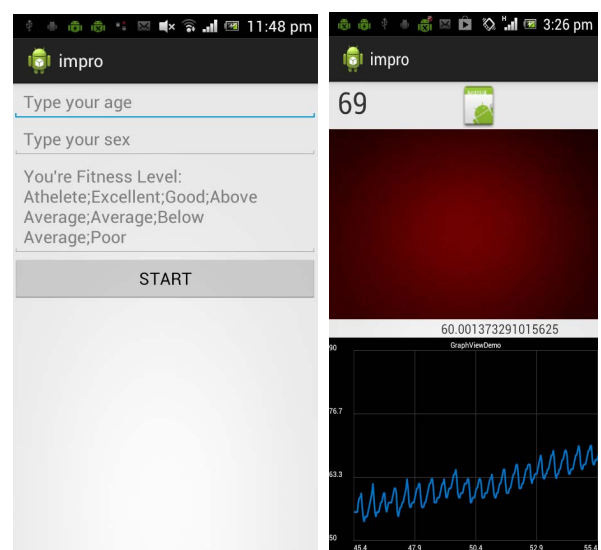

Figure 3. A screen shot of the questionnaire and real time heart beat graph
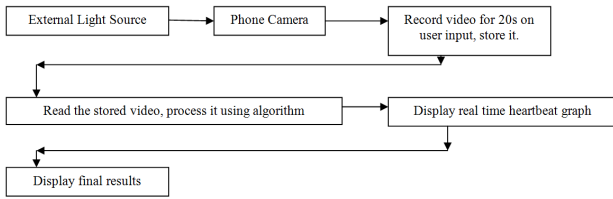
Figure 4. Flow diagram of the algorithm.

frame is resized to 320X240 pixels for reduced computation time. Each frame (hereafter referred to as image) is separated into its red and blue constituents. The following parameters are calculated for each image: mean of red color component (m_r), mean of blue color component (m_b), standard deviation of red color component (sd_r) and the standard deviation of blue color component (sd_b). Here, m_r corresponds to the red DC value, m_b to the blue DC value, sd_r to the red AC value and sd_b to the blue AC value. These values are substituted in equation (1), to calculate the SpO_2 level. If the values of A and B are unknown , they can be obtained after fitting the graph obtained here to the SpO_2 graph obtained through commercial pulse oximeters. The calculated average SpO_2 value of all the 600 frames is then displayed and an average value obtained from SpO_2 graph is saved for further use.

D. Calculating the Heart-beat

After SpO_2 has been calculated, a questionnaire is launched where the user enters his/her 'age', 'sex' and 'fitness level'. Based on the entered parameters, and using data available [7], an ideal heart rate is decided upon for a person satisfying the user's profile. When this has been completed, the user keeps his finger in a similar setup as before and another

screen launches, which shows a real time plot of red DC mean (m_r) data from the image. The m_r values show the variation of received intensity of red colour with time and this can be used to calculate the heartate (equation (2)). Once a stable heartbeat is obtained, the difference is found between the ideal heartbeat rate and the calculated one.

E. Final Step

When all the required parameters have been furnished, the following suggested actions are shown to the user:

1. SpO_2 calculated between 96 and 99 and calculated heart rate within ±15 of the ideal heart rate, Result: Healthy

2. SpO_2 calculated <95 and calculated heart rate within ±15 of the ideal heart rate, Result: The user should try again, if values persist, he should cross check his values with standard equipment

3. SpO_2 calculated <95 and calculated heart rate outside ±15 of the ideal heart rate, Result: Case of worry and should consult a doctor immediately.

A screen shot of the questionnaire and real time heart beat graph is shown in Fig. 3. Flow diagram of the algorithm used in this app is shown in Figure 4. A flowchart showing all the different steps and decisions in the front end of the application is shown in Fig. 5. A similar flowchart for the backend is shown in Fig. 6.

IV.   RESULTS AND FUTURE WORK

We used this developed application to read SpO_2 values for subjects of different age groups. The results are shown in Table I. From the results it can be observed that the results from the developed application follow very closely with standard devices and this is valid for all the ranges of SpO_2 values.
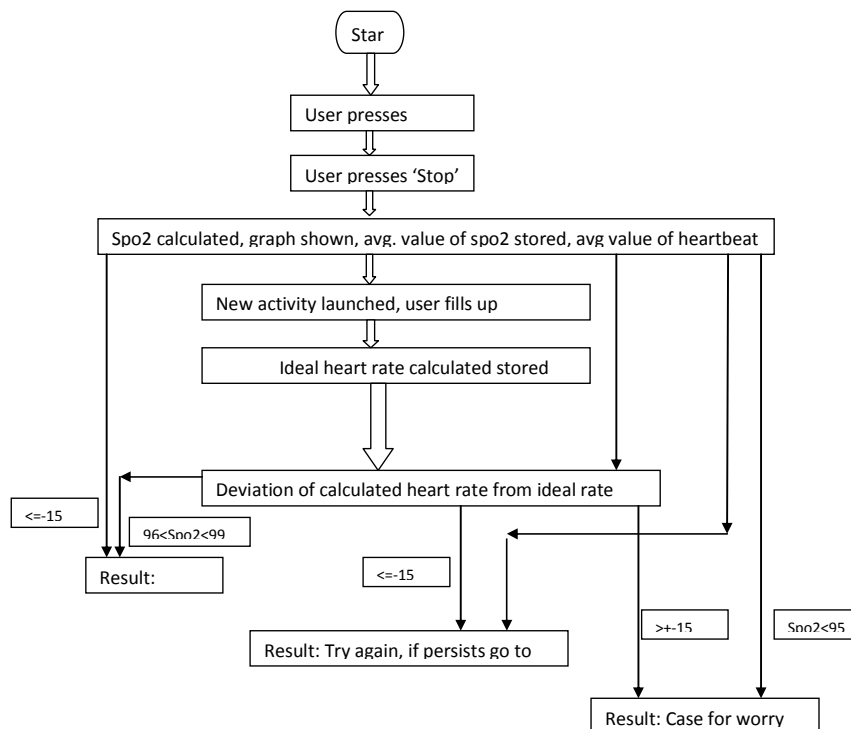

Figure 5. A Flow diagram showing all the steps in the front end of the application

First Activity: This activity contains a holder to show the camera preview and two buttons 'Start' and 'Stop'. Video recording starts with the 'Start' button. Standard recording settings applied to camera

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At the end of 20s,the video is written to the user's sdcard.

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Second Activity: The video is read from the card, individual frames are extracted with Android's built in Android's MediaMetaDataRetriever class using the getFrameatTime() function.

↓

Each extracted frame is parsed into a bitmap and then resized to 320X240 pixels. From every pixel in the frame, the individual red and blue values are extracted and stored in separate arrays. While all this processing is happening on a separate thread, a progress box runs to indicate percentage of completion of computation on the main thread.

↓

The mean and variance of both arrays are calculated. These are taken as the DC and AC components. Now using formula (1), the spo2 levels are calculated for each frame. For each frame, spo2 values are stored in a separate array. Finally after all this computation, the values in the spo2 array are averaged and this value is displayed on a TextView holder alongwith the graph for spo2.

↓

Third Activity: A small questionnaire opens up which asks the user to enter his age, sex and fitness levels. An ideal heart rate is calculated for those particular inputs. Fourth activity launched.

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Fourth Activity: This activity also contains a camera preview. The algorithm scans the changes in red colour and calculates an approximate value for heartbeat. This value is displayed in real time and also stored in an array. After around 20s , the values in the array are averaged out and a final value of heartbeat is calculated.

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Difference is calculated between this heart rate and the standard heart rate. Depending upon the disparities and also the spo2 level, appropriate output relayed to user through messageboxes.
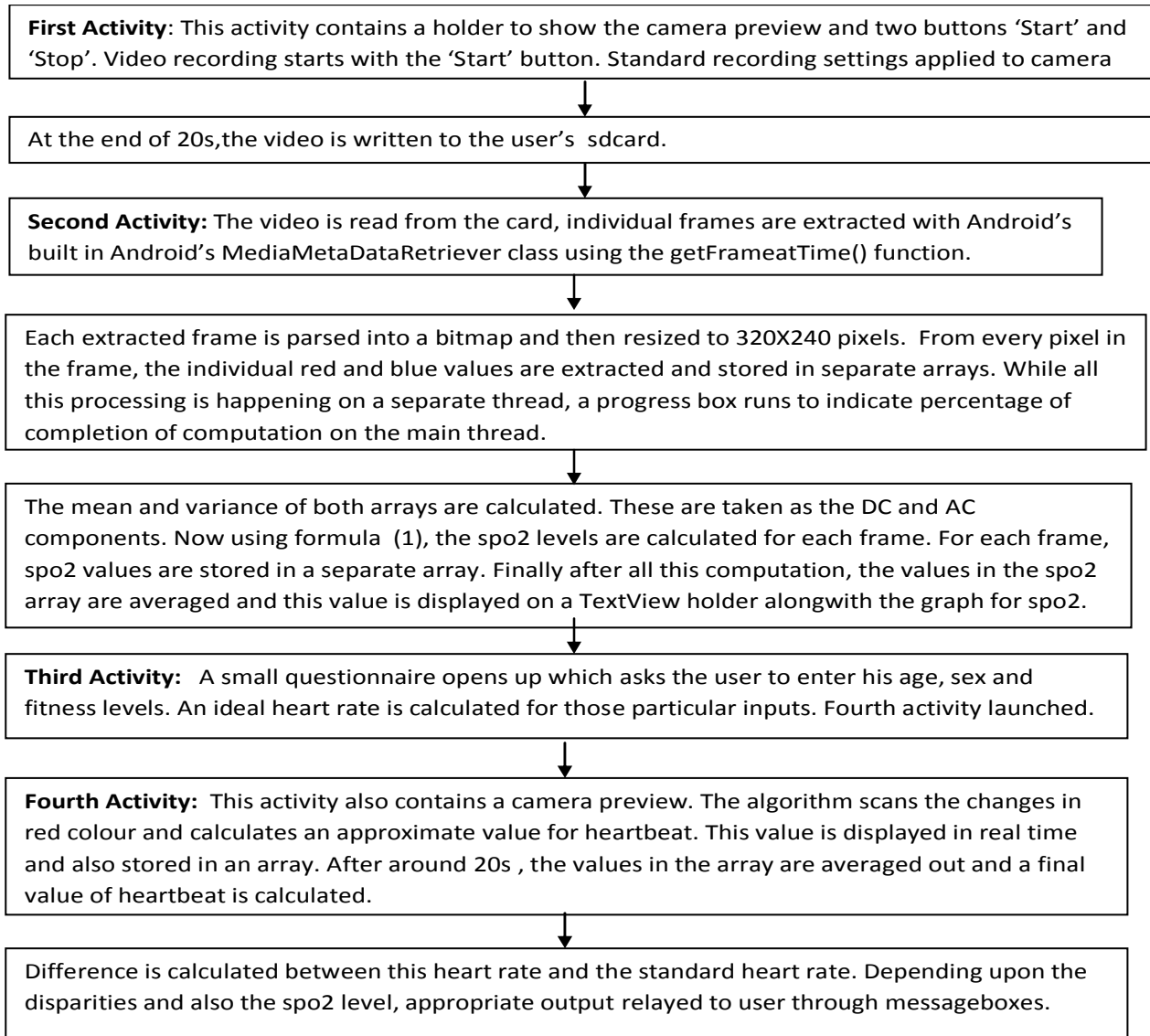
Figure 6. A Flow diagram showing all the steps in the front end of the application.

Work is being done to incorporate other factors to calculate ideal heart rates. Also, low SpO_2 can be linked to a number of different heart defects, for instance, anemia. We are hoping to add other features to the application to create an early warning system.

TABLE I.   OBSERVATIONS

Age-Group	Number of Persons	Standard Pulse Oximeter Reading	Reading from developed application
10-20	2	98	97.2
		98	97.6
20-30	2	98	97
		98	97.4
40-50	2	98	96.8
		98	97
50-60	3	98	97
		99	99.3
		98	98.4
60-70	2	93	92.1
		90	88.7
70-80	1	97	95

V.   CONCLUSIONS

Preventive cardiology holds lot of promise, but easy to use and widely available hardware is necessary to make it an effective tool against cardiovascular diseases. In this paper we show that mobile camera can be effectively used for recording important parameters like heart rate and pulse oximeter. We collected and verified the results for different age groups and overall the results look very promising

VI.   ACKNOWLEDGMENTS

VII.   REFERENCES

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