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Non Invasive Measurement of Parameters for Pregnant Women

Prof. Rasika Beohar
Assistant Professor
MIT World Peace University, Pune, India

Abstract

A pregnant woman must undergoes several tests for measuring some physiological parameters like hemoglobin, pulse rate and others. This becomes important to reduce mortality rate of pregnant women and neonates specially in rural areas. In this proposed method, a non-invasive method for measurement of hemoglobin, oxygen saturation and pulse rate is described. The method proposed uses photoplethysmographic (PPG) signals obtained by illuminating a finger with monochromatic light at two different wavelengths. An empirical equation for calculation of Hb, SpO2 and pulse rate in blood is derived. We have tested our proposed prototype on 41 normal subjects for pulse rate and hemoglobin and the results are compared by clinical methods. The average error rate for pulse rate and hemoglobin are 1.633 and 0.777. Similarly prototype was tested on 5 pregnant women for hemoglobin and then compared with clinical methods. The percentage error found is 0.654.
Keywords: Oxygen Saturation, Photoplethysmograhy, GSM transmission

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I. Introduction

In rural areas, pregnant women are reluctant to do for their regular checkups. Actually the checkup for pregnant women in the first trimester and complete natal checkup is very essential for both the child and the mother. In rural areas, the mortality rate of the child and the women due to carelessness is much more. There is a small or no decline in early neonatal mortality rate (ENMR), which hovers at around 30/1000 live births[18]. ENMR is an indicator of quality of prenatal care. India accounted for 19% (56,000 in numbers) of all global maternal deaths. India presently accounts for nearly 20% of the world child deaths[19]. By using our proposed system pregnant women will be able to check the parameters at home itself. After the tests, the interpretation of test is also required. Moreover, the process of determining hemoglobin content in blood requires few hours to a day for the result to be available. Additionally, if the drawn up blood samples are to be transported, extra care is to be taken to maintain the blood samples. These samples need to be preserved within the temperature range of 1C and 10C. Many times it happens that hemoglobin values measured in different laboratories yield different values for the same sample. Apart from this, an added risk exists in the form of infection if blood is drawn using a syringe. Due to all above limitations, a non-invasive method that avoids taking a blood sample from a syringe will be most welcome. Hemoglobin, Glucose and Pulse Rate are some of the important parameters that are needed to be monitored quite frequently. In the proposed system, these parameters can be easily measured. This system gives the values for multiple parameters that reduce the efforts to go to the laboratory every now and then. Our proposed device can precisely measure these basic parameters at home.

II. Literature survey

Presently clinically used methods are spectrophotometry, hemoglobin cyanide and conductivity based method for measurement of hemoglobin. However these methods are invasive wherein blood sample is taken from human body and then it is tested. It causes pain to the patient and even the results are delayed. In this developed technique non invasive measurement of the hemoglobin parameter is used.

Nirupa et al. [1] developed a non-invasive method of ascertaining the hemoglobin content in blood. The proposed method uses a couple of photoplethysmographic signals obtained by illuminating a finger or earlobe with monochromatic light at two different wavelengths. An empirical equation is used for calculation of hemoglobin content in blood. The attenuation of light through skin-bone-tissue-blood is measured, and well known extinction coefficients of hemoglobin (with and without oxygen) are used in the equation to find out hemoglobin. In this paper hemoglobin is the only parameter to be tested.

Kumar et al. [2] worked on reduction for the complications due to anemia, for which the hemoglobin level needs to be measured. In this discussion, photons at appropriate wave lengths are pumped into the skin on the finger. The transmitted photons from the hemoglobin content of the blood are received at a photo detector which converts them into electrical signal. The received signal strength can be calibrated in terms of hemoglobin content in blood. About 100 real time samples were collected at clinical laboratory. These results were then compared with the method proposed by authors.

Another research presents an overview of the fundamentals in noninvasive physiological monitoring instrumentation. It focus on electrode and optrode in-terfaces to the body, and micro power-integrated circuit design for unobtrusive wearable applications. As the electrode body interface shows a performance limiting factor in noninvasive monitoring systems, practical interface configurations are offered for bio potential acquisition. CMOS transistors are used operated in weak inversion layer so they offer high energy and noise efficiency. In addition to power management, wireless transmission is also been considered. This is proposed by Sohmyung Ha et al.[4]

Absorption of light by oxygenated and deoxygenated hemoglobin is mea- sured at two wavelength 660 nm and 940 nm. This wavelength of light are obtained from red and infrared LEDs respectively. Constant current circuit is designed to drive the LEDs. Photodiode is used to detect transmitted light through an area of skin on finger. Ratio of red to IR signal after normalization is calculated for determination of Hb. This was developed by Doshi et al. [3]. In this research, no transmission of data is done and only one parameter is detected.

A research on real time adaptive algorithm is proposed for accurate motion tolerant extraction of heart rate and oxygen saturation from wearable photoplethysmographic biosensors. The proposed algorithm removes motion artifact due to various sources including tissue effect and venous blood changes during body movements and provides noise-free PPG waveforms for further feature extraction. This algorithm was developed by Rasoul Yousefi et al.[5]. This research is taken as a reference for the photoplethysmographic method.

The determination of the blood glucose level is a necessary procedure in diabetes therapy, where the most common technique is invasive. Painless glycemic control would improve the quality of life of patients by increasing compliance to monitoring blood glucose levels and thus hyper- and hypoglycaemic episodes. This is proposed by Carlos Eduardo et al. [6].

A laboratory assessment of oxygen saturation and the percentage of hemoglobin saturated with oxygen, provides an important indicator of a patients cardio- respiratory status. It is frequently used in the emergency department, during general and regional anesthesia, and in intensive care settings. The method of photoplethysmography is studied from Oxygen Saturation - A guide to laboratory assessment by Shannon Haymond [7].

In [8] the authors have developed sensor device to measure PPG signals at three independent wavelengths continuously. The LEDs used are in the range from 600 nm -1400 nm. The time varying part allows the distinction between the absorbance due to venous blood (DC part) and that due to the pulsatile component of the total absorbance (AC part). In [14], two LEDS (RED IR) as a light source are used and photo diode detects the light. DAQ device is used to give outputs which is a voltage corresponding to the amount of light detected. To determine the pulse rate, first the time that elapses between two successive peaks is determined. Similarly AC and DC voltages are determine to calculate the percentage of oxygen. Based on voltages the modulation ratio, which is the ratio of magnitude of RED waveform to that of IR waveform is caalculated.

Janis Spigulis et al.[16] have proposed three wireless PPG monitoring de- vices embedded in glove, sock, and hat. These are then connected to PC or mobile phone by means of the Bluetooth technology. First results of distant monitoring of heart rate and pulse wave transit time using the newly developed devices were presented. J.P.Phillips et al. [17] suggested a comparison between two sensors a probe and phantom producing a signal which is capacitance plethysmograph (CPG). The results shows that ratio of PPG to CPG increases with increasing concentration and is very less affected by changes in pulse pressure.

III. PROPOSED METHOD

A. System Overview

The amount of light received by the detector indicates the amount of oxygen bound to the hemoglobin in the blood. Oxygenated hemoglobin (HbO2) absorbs more infrared light than red light whereas deoxygenated hemoglobin (Hb) absorbs more red light than infrared light. By comparing the amounts of red and infrared light received, the instrument can calculate the SpO2 reading. The PPG signal consists of a large steady DC component, which is attributed to the total blood volume of the examined tissue, and a pulsatile AC component, which is synchronous to the pumping action of the heart. The AC component is much smaller in magnitude than the DC component. The sensor to be mounted on an extremity such as finger or an earlobe of patient being tested consists of two light emitting diodes on one side and a photodiode on the other side of a soft plastic clip. Mostly the LED used are infrared LED in invisible range. LED emits light at 700nm and 900nm. The LEDs are switched ON in sequence through software to count 10 samples in every cycle. The output of sensor is available in analog and digital form. The analog signals are used for SpO2 and Hemoglobin, while digital signal is used for pulse rate calculation.
The extracted PPG signal are sampled and acquired by PIC16f877 controlled by a dedicated program.

B. Mathematical Implementation

For this proposed method, infrared LED of 700 nm and 900 nm is used. The output from the photodiode is sampled and filtered out to remove signal due to arterial blood, capillaries and veins. The signal is amplified for the attenuation taking place due to skin and bone tissues. The output consists of analog as well as digital output. The relationship between the measured PPG voltages and the path length had to be determined empirically. From each data set, the average of the peak to peak voltages of the two PPGs (obtained at both the IR wavelengths), namely Vir1 and Vir2 are computed. Utilizing the ratio.

$$r = \frac{Vir_1}{Vir_2} \qquad (1)$$

The oxygen saturation in arterial blood (SpO2) for each data set is deter- mined using the relation[2]

$$SpO_2 = \frac{(e_{HB1} - r e_{HB2})}{e_{HB1} - r e_{HB2}) + (r e_{HBO2} - e_{HBO1})} \quad (2)$$

Using the computed SpO2, hemoglobin can be determined as[2]

$$T_F = -0.0007106 + 0.038854 V_{ir2} \quad (3)$$

Using the value of TF, hemoglobin concentration in blood (Hb) is calculated as[2]

$$Hb = \frac{V_{ir2}}{(e_{HB2}(1 - SpO_2) + e_{HBO2} \square SpO_2)T_F} \quad (4)$$

IV. Hardware Implementation

IR LED emits light at 700nm and other IR emits light at the 900nm. The extracted PPGs are sampled and acquired by a filter and amplifier stages and then given to microcontroller, which is controlled by dedicated program. The necessary timing and control signals are generated using a PIC16F877A microcontroller. The parameter of SpO2, Hemoglobin and pulse rate can be transmitted to doctors mobile through GSM SIM300 technology.

HRM-2511E sensor manufactured by Kyoto Electronic Co., China is used. These sensors operates in transmission mode. The sensor body is built with flexible Silicone rubber material so that the finger can be tightly placed inside

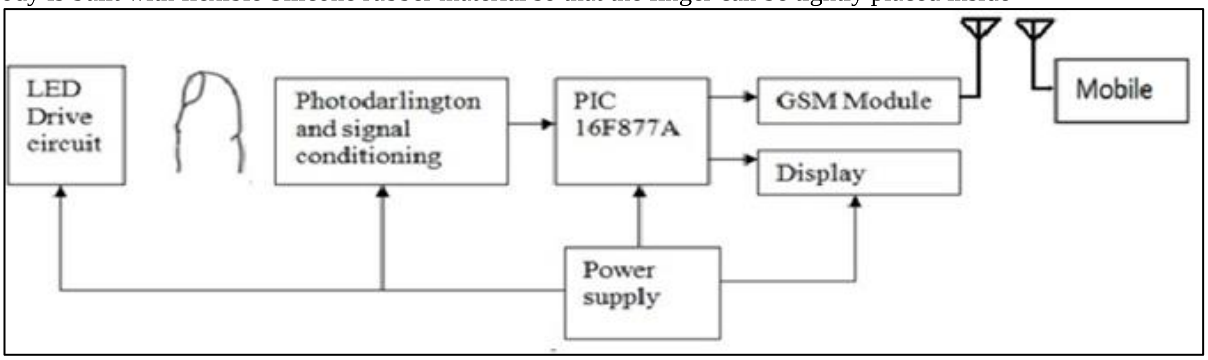

Fig. 1: Block Diagram of the system

the sensor. These sensors are enough flexible to allow almost any size of the finger. IR LED and a photodetector are placed on two opposite sides facing each other. When a fingertip is plugged into the sensor it is illuminated by the IR LED. The photodetector receives this transmitted light through the human tissue. The PPG signal coming from the photo detector is weak and noisy. So there is a need of an amplifier and filter circuits to boost and clean the signal. A two stage amplifier and filter is used with HPF and LPF to reduce the variations from blood. This signal is then given to non inverting buffer with unity gain. Although the HRM-2511E sensor fits on almost any of the five finger tips, it has been found that the sensor performance is better, if used on the middle or index finger. The flexible elastic silicone rubber case helps to attach the sensor to the finger. The IR LED illuminates the finger from the top. The processing software on PIC16f877A is used to develop an application that reads the incoming ADC samples from the microcontroller, and process them to extract the PPG signal and heart rate.

As we want to measure three different parameters hemoglobin, Spo2 and pulse rate, two sensors with two different wavelengths are taken. The analog output from both the sensors is taken for the measurement of SpO2. From SpO2, hemoglobin of the patient can be calculated. From the digital output of the left sensor the measurement of pulse rate is done. All the three parameters are calculated by using the Eq. (1) Eq. (4) provided in the mathematical implementation. These parameters are displayed on the 8bit LCD display, so that continuous monitoring of the patient can be done. These parameters can then be transmitted to the doctors place through GSM SIM300. As the hardware is for continuous monitoring, it is not necessary for the doctor to know minute to minute reading of the patient. Only the critical reading of the patient needs to be transmitted. To avail this a small switch is kept. If the switch is pressed as a input, then only the information would be transmitted to the doctors through SMS.

V. Experimental Results

The results are computed on the basis of parameters that are continuously monitored on the subjects. The sensors are activated on the subjects index finger. Hemoglobin, SpO2 and pulse rate is displayed and transmitted to the doctors mobile through SMS.

For the experimentation 11 subjects were tested from Siddhi Hospital, Pune. Pulse rate, SpO2 and Hemoglobin were recorded using the hardware. For all the three parameters comparison was done. The subjects were analyzed using the pulse oximeter device used in hospital and the proposed prototype. Figure 4 shows oximeter pulse rate (PR) in blue line whereas prototype project reading for pulse rate red line. The mean percentage error was found out to be 2.2016. Similarly Figure 5 gives the oximeter readings for SpO2 in blue line and prototype readings of SpO2 in red line. The mean percentage error for the SpO2 is 2.241. The graph shows that recorded values are very much close to the actual one.

Another results were carried out at Bharti Vidyapeeth College of Nursing, Pune for the class of 41 students from 4th year BSc. All these students were of the age group from 19 to 21 year. The pulse rate, SpO2 and hemoglobin was recorded with the help of prototype. At the same time manual pulse rate was

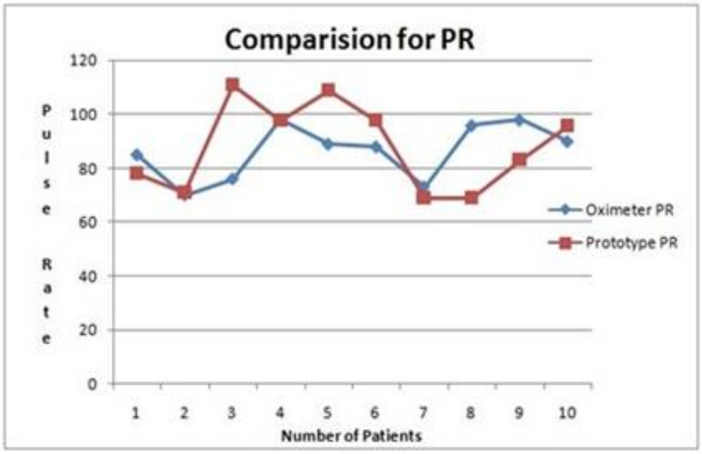

Fig. 2: Comparison for oximeter and prototype for PR

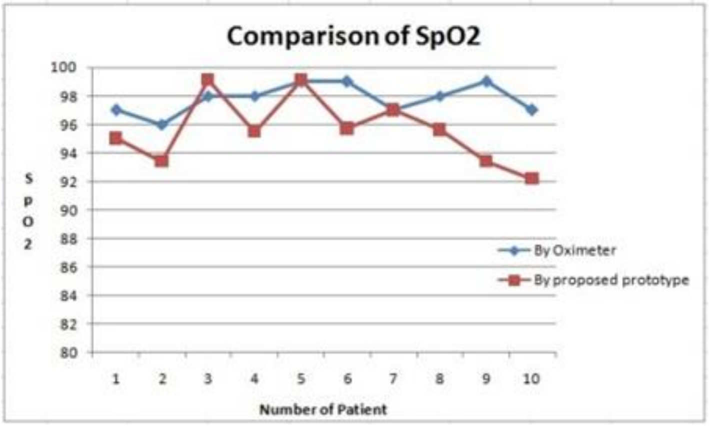

Fig. 3: Comparison for oximeter and prototype for SpO2

recorded for all subjects. Their hemoglobin from prototype and the pathological lab reports were compared. Mean for both type of readings was calculated as shown in the Figure 6 and 7. The percentage error for hemoglobin was 0.777 and pulse rate was 1.633 respectively.

As the target patients of the project are pregnant women, this prototype was also tested on some pregnant women. Five pregnant women were tested for their Hb parameters. All the subjects are from the age group of 22 to 28 years. The mean of calculated Hb and their respective pathological reports Hb is taken and the results are displayed in Figure 8. The percentage error of 0.654 is observed.

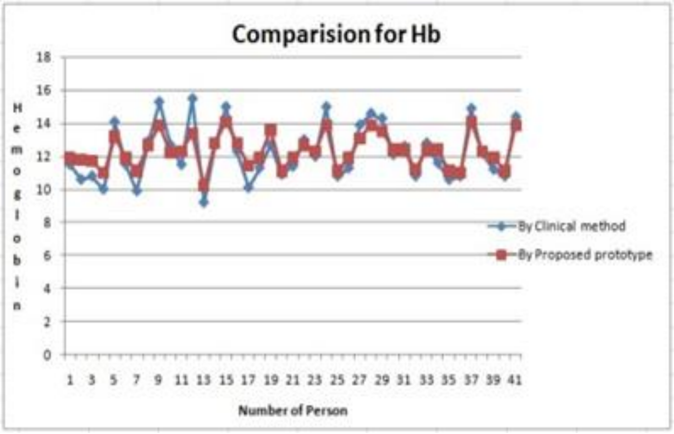

Fig. 4: Comparison for Manual and calculated Hb

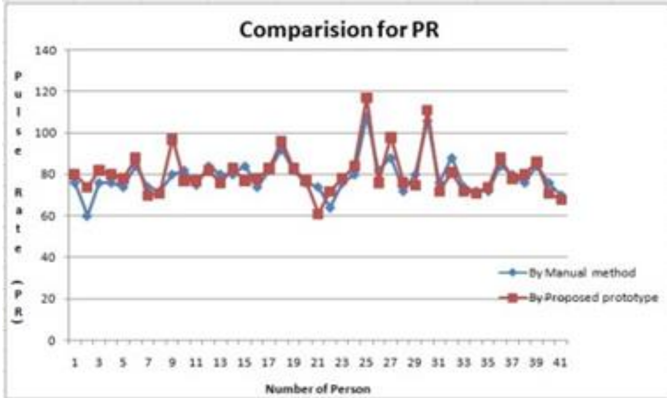

Fig. 5: Comparison for Manual and calculated PR

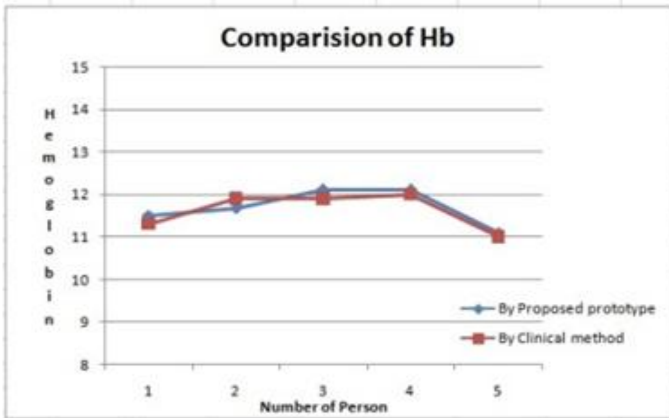

Fig. 6: Comparison for Manual and calculated Hb

VI. CONCLUSION

Non invasive measurements have been proposed using the method of photoplesthysmography. This method can be used to determine the parameters, hemoglobin, SpO2 and pulse rate using empirical formule. Calibration of the parameters is done by using software. Thus the proposed prototype can be used for calculating hemoglobin and pulse rate of the patient and can be transmitted it to doctors. The average error rate of 1 to 2% is observed in pulse rate. The average error rate of 2 to 3% is observed for SpO2. Similarly, average error rate of about 1% is observed in hemoglobin.

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