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A Review On Non Invasive Measurement For Hemoglobin

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Abstract - In developing nations like India, rural areas are more as compared to urban areas. People from rural areas specially women don't do their regular checkup. Routine checkups can avoid diseases helps in mortality rate to a very large extent. The normal tests includes hemoglobin, blood sugar, ECG, urine and thyroid. All of these tests require blood sample of the patient. In this proposed method, a non-invasive method of ascertaining the different physiological parameters content in blood is described. The method proposed here uses a couple of photoplethysmographic (PPG) signals obtained by illuminating an extremity such as a finger or earlobe with monochromatic light at two different wavelengths. An empirical equation for calculation of hemoglobin content in blood is derived using a model for attenuation of light through skin-bone-tissue-blood in that extremity. The availability of PPGs facilitates the computation of hemoglobin content, heart rate, heart rate variability and oxygen saturation in arterial blood (SpO2) as well.

Keywords - Photoplethysmography, oxygen saturation, Pulse oximeter.

I. INTRODUCTION

Health care is one of the most important aspects in human life. Right from childhood up to the old age different health issues have to be considered. Due to advent of electronics devices the measurement and detection of various diseases have been possible. These devices have become so relied that doctors, physicians, nurses, occupational therapists and other health care professionals can carry out their work suitably. Devices like ECG, EMG, EEG, pulse oximeter have not only revolutionized the field of medicine with their rich technology, but also have increased the quality of medical care that the patient receives.

Analysis of blood substances such as hemoglobin, glucose, protein are important parameters for health condition monitoring. Traditionally, blood sample is taken by using a needle in a pathological lab. Some chemical process such as enzyme reaction is required before the final value for concentration is read. Reagents involved in such processes are expensive for both the hospital and patient which is not affordable by the people in rural areas. Knowledge of hemoglobin content in blood helps a medical practitioner diagnose several ailments as well as the health condition of a patient. Today, to determine hemoglobin content in blood, a few cubic centimeters (cc) of blood is drawn from the veins of the patient being tested. The drawn up blood is then subjected to chemical analysis and the hemoglobin content in terms of milligram of hemoglobin per deciliter (mg/dL) of blood is ascertained. To implement this procedure, the services of following persons are required:

(i) Trained paramedical staff : to extract the blood sample

(ii) Laboratory technician : to perform the chemical analysis
(iii) Pathologist : to verify

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 1°C and 10°C. 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 the above these aspects, a non-invasive method that avoids taking a blood sample from a syringe will be most welcome.

II. RELATED WORK

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 the developed technique non invasive measurement of the hemoglobin parameter is used.

Lourdes Albina Nirupa and Jagdeesh Kumar [1] developed a non-invasive method of ascertaining the hemoglobin content in blood. The method proposed here uses a couple of photoplethysmographic signals obtained by illuminating an extremity such as 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, Dr. Ranganathan [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 are then compared with method proposed.

Another research presents an overview of the fundamentals in noninvasive physiological monitoring instrumentation. It focuses on electrode and optrode interfaces to the body, and micro power-integrated circuit design for unobtrusive wearable applications. As the electrode/optrode–body interface shows a performance limiting factor in noninvasive monitoring systems, practical interface configurations are offered for bio potential acquisition, electrode–tissue impedance measurement, and optical bio signal sensing. CMOS transistors are used operating in weak inversion layer where they offer high energy and noise efficiency. Apart from this some more technologies for electrode–tissue impedance measurement, photoplethysmography, functional near-infrared spectroscopy, and signal coding and quantization are made with additional guidelines. In addition to this 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 measured at two wavelength 660 nm and 940 nm. These wavelengths of light are obtained from red and infrared LED. 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 Rajashree Doshi and Anagha Panditrao [3]. In this research no transmission of data is done and only the hemoglobin 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 - the percentage of hemoglobin saturated with oxygen - provides an important indicator of a patient's cardio-respiratory status and is frequently used in the emergency department, during general and regional anesthesia, and in intensive care settings. The method for the oxygen saturation calculation and the formula to be developed are taken as reference 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 LED'S (RED & IR) as a light source are used and photo diode detects the light. DAQ device outputs a voltage corresponding to the amount of light detected, and the final signal is a pulse. To determine the pulse rate, first the time that elapses between two successive peaks is determined. Second to calculate the percentage of oxygen, AC & DC voltages are determined. Based on voltages the modulation ratio is calculated, which is the ratio of magnitude of RED waveform to that of IR waveform. Janis Spigulis et al.[16] has proposed three wireless PPG monitoring devices 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 show that ratio of PPG to CPG increases with increasing concentration and are very less affected by changes in pulse pressure.

The comparison of various algorithm for non invasive measurement of hemoglobin and heart rate are described in Table 1 with method used and their limitations.

III. EVALUATION CRITERIA

The sensor to be mounted on an extremity such as finger of a 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 red LED and a infrared LED. Red LED emits light at wave $length_1$ while infrared LED emits light at the $wavelength_2$. The LEDs are switched ON and OFF in sequence or they are multiplexed. The extracted PPGs can be sampled and acquired by a suitable data acquisition hardware controlled by program. A typical PPG will contain three main components:

(i) A dc part due to attenuation by epidermis, dermis, skin, soft bone and tissue.
(ii) A slow varying ac part due to blood flow in capillaries and veins
(iii) A pulsating signal due to attenuation by arterial blood.

Table 1. Comparison for different research work

Authors	Introduction	Method	Limitations
Lourdes Albina et al.[1]	A non invasive method of ascertaining hemoglobin content using photoplethysmographic (PPG) signals is presented here	Oxygen saturation	Hemoglobin was the only parameter to be tested
Kumar R et al.[2]	Instead of invasive, non invasive methods are used to take the blood sample.	photoplesthy smography	Error rate is more
Sohmyung Ha et al. [4]	Noninvasive physiological monitoring instrumentation with a focus on electrode and optrode interfaces to the body, and micro power-integrated circuit design for unobtrusive wearable applications.	electrode–tissue impedance measurement , and optical bio signal sensing.	The electrode/optr ode–body interface is a performance limiting factor
Rajashree Doshi et al. [3]	Absorption of light by oxygenated and deoxygenated hemoglobin is measured at two wavelength from red and IR LED. Transmitted light through an area of skin on finger was detected by a photodiode. Ratio of red to IR signal after normalization is calculated for determination of Hb.	Non invasive method	No transmission of data to the doctor
Rasoul Yousefi et al.[5]	A real time adaptive algorithm is proposed for accurate motion-tolerant extraction of heart rate (HR) and pulse oximeter from wearable PPG 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.	Real time adaptive algorithm and photoplethys mographic sensors	Reference for photoplethysm ographic sensor
Carlos Eduardo et al.[6]	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	Bio impedance and absorption spectroscopy	Errors in bio impedance
F. K. Che Harun et al [12]	Paper proposed a color coded bracelet prototype for heart rate monitoring system communicating with Zigbee.	Pulse oximeter and Zigbee transreceiver	Used for pulse oximeter reference

Generally for red LED we choose 600 nm to 700 nm and for infrared frequency > 800 nm. The output from the photodiode has to sampled and filtered out to remove signal due to arterial blood and capillaries and veins. The signal has to be amplified for the attenuation taking place due to skin and bone tissues. The output consists of ac parts Vr which voltage at red LED and Vir which the voltage at infrared LED of the PPGs. 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 red and IR wavelengths), namely *Vr* and *Vir* can be computed. Utilizing the ratio

$$r = \frac{\text{wavelength}_1}{\text{wavelength}_2} \tag{1}$$

The oxygen saturation in arterial blood (SpO_2) for each data set is determined using the relation

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

Using the computed SpO_2 and the measured hemoglobin (*Hbm*) values the concentrations of *Hb* and *HbO*, namely, c_{Hb} and c_{HbO} can be determined as

$$c_{HbO} = SpO_2\, Hbm$$
$$c_{HbO} = (1 - SpO_2) Hbm \tag{3}$$

These values are then substituted in equation and the value of T_F for each data set can be determined. From the data, *Vr* and *Vir* are extracted and oxygen saturation SpO_2 is determined utilizing the following equation. Then the path length T_F is determined using the equation

$$(T_F = -\,0.0007106 + 0.038854\, Vir) \tag{4}$$

Using the value of T_F, hemoglobin concentration in blood (*Hbc*) is calculated as

$$Hbc = \frac{Vir}{(e_{HBIR}(1 - SpO_2) + e_{HBOIR}\, SpO_2)\, T_F} \tag{5}$$

IV. PROPOSED BLOCK DIAGRAM

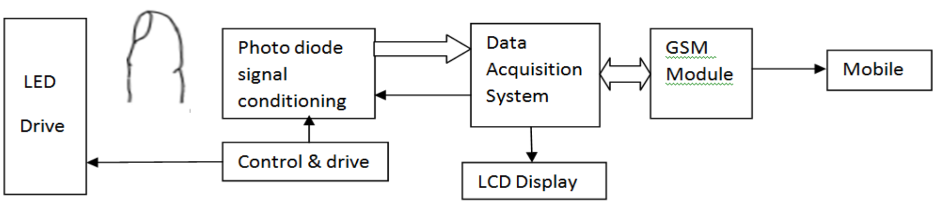

Figure 1. Block diagram of proposed block diagram

LED D1 emits light at wave length$_1$ and D2 emits light at the wavelength$_2$. PPG1 and PPG2 signals corresponds to wavelengths 1 and 2. The extracted PPGs are sampled and acquired by a suitable data acquisition hardware controlled by program. The necessary timing and control signals are generated using a PIC16F877A microcontroller. Utilizing a data acquisition card interfaced to the PC through the USB, the red and IR PPG signals would be sampled and processed. The parameter of Hemoglobin and heart rate can be transmitted to doctors mobile through GSM technology.

V. CONCLUSION

In this paper, different non invasive measurements have been proposed using different methods like photoplesthysmography, bio impedance and oxygen saturation. Bio impedance has the limitations for which different algorithms are required to be used. Thus photoplesthysmography method can be used to determine the parameters. Empirical formulas can be used to calculate the hemoglobin and pulse rate. Calibration of the parameters can be done by using the empirical formulas. The above references can be used building a system consisting of non invasive sensors used for calculating hemoglobin and heart rate of the patient and transmitting to the doctor place.

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