International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 10 (2018) pp. 7853-7856


# Non-Invasive Haemoglobin Estimation through Embedded Technology on Mobile Application

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**Abstract**

This paper presents a novel approach in the estimation of non-invasive haemoglobin concentration. The proposed method in the paper involves both hardware and software. The hardware part is used for the implementation of the non-invasive haemoglobin measurement using Photo-plethysmography (PPG) principle. The PPG signals are acquired by illuminating an extremity such as a finger with monochromatic light at a certain given wavelength. In the proposed method the haemoglobin is measured at the tip of any finger, an Infrared LED and a Red LED are used as a light source and a photodiode is used for detecting the absorbed light. The empirical equation for calculation of hemoglobin content in blood is derived using a model for attenuation of light through skin-tissue-blood in that extremity, using well known extinction coefficients of hemoglobin (with and without oxygen). Further analysis of the obtained signal is done using software methods like signal processing and filtering. The conclusion for the measurements with a suitable solution is presented and further refinement in the study is necessary.

**Keywords:** Haemoglobin, LED, Photo-plethysmography,

## INTRODUCTION

Haemoglobin (Hb) is normally found in red blood corpuscles that are used for the transportation of oxygen ($O_2$) from the lungs to the body tissues and also return the carbon dioxide ($Co_2$) from the tissues back to the lungs. It is actually a protein molecule and four of them together combine for the formation of a haemoglobin molecule. The usual normal range of Haemoglobin (Hb) concentration in blood is about 12 - 15 gm/dl for females while it is 13.5 - 17.5 gm/dl for males. Haemoglobin (Hb) values may differ according to the condition of the subject, which can be either lower or higher than the range resulting in different types of diseases. If Hb concentration is lower than normal levels then it is termed as anemia and it could be as a result of kidney, liver related diseases and iron deficiency whereas high levels of haemoglobin (Hb) which is termed as polycythemia is found mostly in a person due to factors such as tobacco, smoking, lung diseases, etc.

With day-to-day improvement of technology and science the increase in the demand of use of non-invasive methods for the estimation of the clinical/medical parameters is heavily growing. Thus, one among all the recent advances is the measurement of Haemoglobin concentration with the help of Photoplethysmography (pulse oximetry) procedure.

Kawther Abo Alam's aimed in the report is the determination of Non-invasive total hemoglobin (tHb) concentration, methemoglobin (MetHb) ratio, reduced hemoglobin (RHb) ratio, oxyhemoglobin (O2Hb) ratio and carboxyhemoglobin (COHb) ratio [1].

The two approaches mentioned are:

- Modified Lambert-Beer's law forms the basis for this approach. In this approach the estimation of the pre-mentioned physiological variables is performed by two methods. For each method there is a different equation and all the equations are derived from the basic principles of modified Lambert-Beer law and pulse oximetry.
- Based on the generated fuzzy rule base a fuzzy expert system was developed to perform the measurements.

Based on the literature survey, O. Abdallah et al, have used earlobe and a finger as an extremity for the purpose of illuminating the light source [2]. As the motion artifact caused by the patient will induce some disturbance, to overcome this, an adaptive filter is used. The Assessing System consists of an Earlobe and a fingertip sensor developed for the purpose of detecting the PPG signals. A printed circuit (PCB) was also developed for driving the LEDs and to detect the signals from the photo detector. The signals measured have been digitalized and then further processed using LabVIEW Software.

Kumar R et al has proposed a non-invasive optical technique for Hb concentration measurement. The working system consists of LEDs with two different wavelengths. When the light is incident on an extremity the detected light is measured by a photodiode which in turn sends the output to current-voltage converter, and further coupled with the Analog to Digital converter [3]. The follow-on of the ADC is given to a microcontroller for processing. The output is displayed on an LCD display. This trial was lead with both the LEDs individually. The result obtained through the detector reflects the Haemoglobin value in blood. The result for one of the LED shows much more correlation with clinically measured invasive Hb value than the other.

Kumar Abhishek et al. proposed a low cost process for the assessment of blood parameters (such as heart rate and Haemoglobin) using photo-plethysmography (PPG) procedure. LEDs act as the light source and a photo transistor is used to detect the change observed with the light source is incident on the fingertip [4]. The change detected by the photo

transistor is subjected to various analog filters and the resultant filtered output is sent to the computer with the help of a microcontroller interface for further estimation of parameters using MATLAB.

A. Mohamed Abbas et al, has considered to measure the contents of haemoglobin in blood using the photo-plethysmographic (PPG) signals. Calculation of this haemoglobin content was derived using the well-known hemoglobin extinction coefficients, data collected from the clinical study and skin-tissue-blood attenuation in that extremity through light [5]. Photo-Plethysmo-Graphic (PPG) algorithm is used for the purpose of fetching the data for computation and for the recording of the signal Sigview software is used. The resultant obtained by using the Photo-Plethysmo-Graphic (PPG) is taken for further regressive analysis and then to conclude, the haemoglobin content was determined.

## PROPOSED METHOD

The proposed method for the system consists of a light source and a detector along with the signal conditioning circuit. Here, the light source is the Infrared and Red LED with a photodiode acting as a detector. For the acquisition and processing a Microcontroller is used.

Embedded Software is required to form a communication medium between the Sensor and PC. The incoming values from the sensor are recorded and stored using RS232 for further analysis.

These recorded values are used for calculation of both $Spo_2$ and Haemoglobin Measurement (Hb).

The complete block diagram of the proposed method is mention in the figure-1.

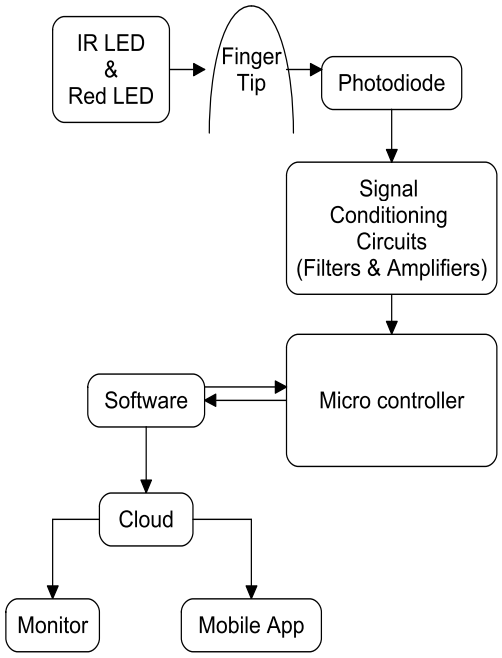


**Figure-1.** Block Diagram of the Proposed Method

### Oxygen Saturation Percentage ($Spo_2$)

The $Spo_2$ is measured using both the Red LED and IR LED. The values of both AC and DC are calculated from the acquired PPG signals and applied to the formula for the estimation of $Spo_2$. The A and B in the figure are the regression coefficients.

The flow of the estimation is presented in the form of block diagram in the Figure-2.

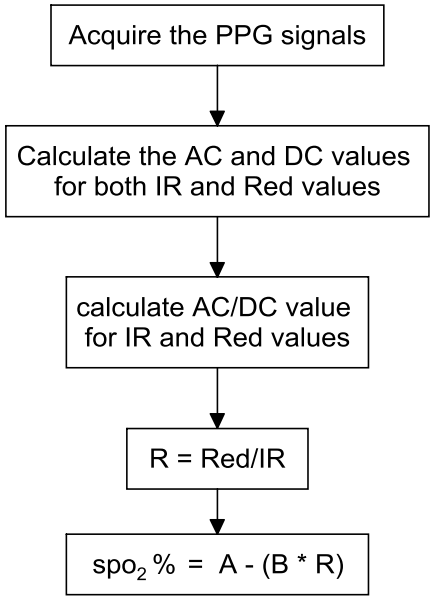


**Figure 2.** Program Flow for $Spo_2$ Measurement

### Non-invasive haemoglobin Measurement

The non-invasive measurement for the estimation of haemoglobin is carried out using the principles of beer-lamberts law.

The pseudo code is as follows:

The AC and DC values are acquired from the PPG signals measured.

The extinction coefficients ($\varepsilon_{HBO2}$ , $\varepsilon_{RHB}$) are taken at the two wavelengths [2].

The value of $X_\lambda$ is calculated for each wavelength.

Solving the below equations, the concentrations for the calculation of Haemoglobin for two different wavelengths [1].

$$\left(\frac{AC}{DC}\right)\lambda_1 = X_\lambda \left(\frac{AC}{DC}\right)\lambda_2[\varepsilon_{HBO2}(\lambda_1)C_{HBO2} + \varepsilon_{RHB}(\lambda_1)C_{RHB}]$$

$$\left(\frac{AC}{DC}\right)\lambda_2 = X_\lambda \left(\frac{AC}{DC}\right)\lambda_2[\varepsilon_{HBO2}(\lambda_2)C_{HBO2} + \varepsilon_{RHB}(\lambda_2)C_{RHB}]$$

The summation of all the concentrations will give the Total Haemoglobin concentration.

$$Hb = C_{HBO2} + C_{RHB}$$

**Thingspeak Application**

An IOT (Internet of Things) platform which lets the user to store and collect data from the sensors to the cloud to develop the applications based on IOT. The ThingSpeak IoT platform will provide applications that will let the user visualize and analyze user data in any of the following software tools such as in MATLAB, and then present the appropriate action on the data. The data from the sensor to ThingSpeak will/can be sent by the following: BeagleBone Black, Raspberry Pi, Arduino, and other hardware.

The step by step procedure for uploading the calculated Hb data :

- Create account
- Installing Thingspeak support tool box
- Creating a private/public channel after signing up in thingspeak website.
- Using thingspeak functions write the calculated output to the previously created channel.

**RESULTS**

The IR LED and Red LED graphs obtained are shown in the following Figure-3 and Figure-4.

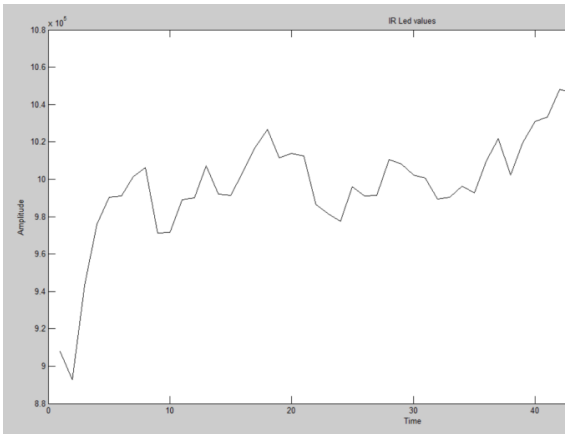


**Figure-3.** IR LED Graph

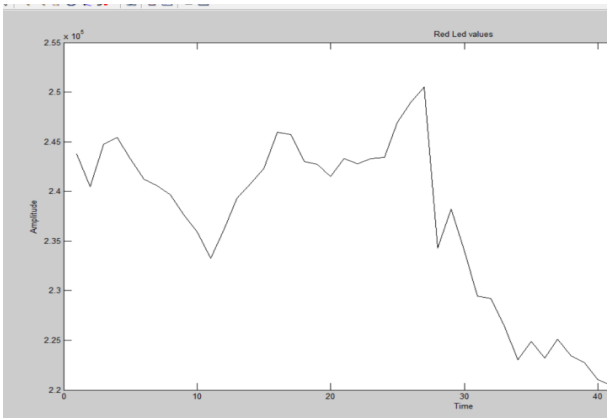


**Figure 4.** Red LED Graph

The $Spo_2$ % calculated by taking the average of the $spo_2$ % obtained for at least 10 samples is shown in the Figure-5.

```
avspo2 =

  368.5489


averagespo2 =

   92.1372
```

**Figure 5.** Screenshot of $Spo_2$ %

The Haemoglobin (Hb) concentration is compared with invasive and non-invasive technique with the approximation of $X_\lambda$ values is mentioned in the following Table-1

**Table 1.** Comparison of Haemoglobin Values

| Subjects | $X_\lambda$ value | | Hb gm/dL (Non-Invasive) | Hb gm/dL (Invasive-Tested in Diagnostic center) |
|---|---|---|---|---|
| | $\lambda_1$ | $\lambda_2$ | | |
| A | 0.25 | 0.57 | 8.47 | 8.8 |
| B | 0.25 | 0.29 | 12.43 | 12.4 |
| C | 0.25 | 0.27 | 13.15 | 13.5 |
| D | 0.25 | 0.2 | 17.33 | 17.3 |

The result obtained in the software is sent to the thingspeak private channel and can be viewed in the thingspeak application with the help of channel ID and a read API key. The mobile application is available in the Play store for free download.

The following figures (Figure-6 & Figure-7) are the screenshots of the outputs sent to the thingspeak cloud.

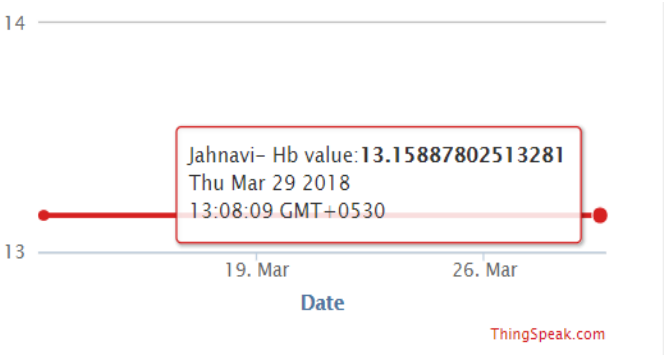


**Figure 6.** Screenshot of Hb data in Thingspeak channel


**Figure 7.** Screenshot of Thingspeak data

## CONCLUSION

Generally, invasive measurement of physiological parameters has many disadvantages such as blood loss, lack of continuous measurements, time consumption, risk of infection and pain for some patients.

The main objective of the proposed work is to measure Haemoglobin (Hb) concentration non-invasively. The $Spo_2$ is also measured along with the Haemoglobin and the result obtained doesn't show much variation with the procedures that are available in the market.

The Hb parameters obtained are studied and the conclusions for the result is drawn based on the relative study. The non-invasive measurement results are matched with the invasive measurements for calculating error approximations. Further normalization of values is under development. The measured non-invasive haemoglobin from the software is sent to the thingspeak cloud and the data can be viewed by the medical practioner at any given time while an Internet connection is available.

For future research an automatic selection system can be developed and employed for the selection of $X_\lambda$ value with further approximations.

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