Non-Invasive Hemoglobin Monitoring System

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***Abstract*—This noninvasive hemoglobin measurement can measure hb levels without the use of any needles. The device uses specific, safe wavelengths of red and infrared light (660nm, 730nm, 850nm, 940nm) to shine through the patients' fingers. The sensor measures how much light you are absorbing. Then the Raspberry Pi filters out any background noise and the algorithm inside will give you an exact value of your hb levels in g/dL. This SMS gets sent to your mobile phone and shows up on your LCD screen. You can see if your levels are normal or anemic in under 50 seconds. As the design was kept as low cost as possible it is quick, cheap and easy to use for medical purposes.**

***Index Terms*—Non-invasive, Hemoglobin (hb), PPG signal, raspberry pi**

I. INTRODUCTION

Monitoring hemoglobin can normally be done via an invasive method. This can cause discomfort for the patient and requires laboratory equipment, and a trained individual. The hb non-invasive hemoglobin monitoring allows hemoglobin to be monitored in a noninvasive way. It uses an optical sensor to capture characteristics and convert them to an approximate value for hb. This makes monitoring routine and allows everyone to easily determine their hb. Hemoglobin is a vital protein in red blood cells that carries oxygen around all the tissues in the body. It contains a high amount of iron found in the heme group. This heme group allows oxygen molecules to attach to it allowing efficient transport. The overall health of a person can be determined by how much Hb is concentrated in the blood. Non-invasive methods can be used to determine how much hb is present in a person known as Hb monitoring. This project replaces invasive methods of blood collection with optical sensors. We will be using optical sensors to determine how much Hb there is. We will collect data from the optical sensor using sensors, then use a micro-controller such as Raspberry Pi to analyses data. We can use certain formulas to calculate the percentage of Hb. We can display this result on an LCD panel or mobile. This cannot replace laboratory diagnosis but provides a simple and painless way to calculate the percentage of Hb.

The Computer Vision and Machine Learning module is the brains of the lowest cost noninvasive hemoglobin monitor. It takes four optical signals (660nm (sensitive to deoxy-hemoglobin), 730nm (isosbestic point), 850nm (sensitive to oxyhemoglobin), 940nm (water reference)) from the tip of a finger and converts them to a concentration of hemoglobin in grams per decilitre (g/dL) in 50 seconds, without taking any samples of blood. The LED light is controlled by the Raspberry Pi using the MOSFET and are picked up by the OPT101 photo diode. This provides a Photoplethysmography (PPG) signal which will be sampled at between 100-200Hz using the ADS1115 ADC.

However, this raw data may be affected by several factors such as ambient lighting, movement artefacts, breathing patterns and also has a large DC component due to skin, bone and venous blood. This makes it difficult to find the AC components of the signal which can give us information about the hb concentration. To overcome this issue, we perform some pre-processing using computer vision techniques. This includes background subtraction in image processing. We first detect the ambient light signal when the LEDs are turned off and subtract this from the signal.

II. METHODOLOGY

The methodology of the proposed system is broken down into several stages beginning with sample preparation and data collection, followed by processing, display of results, and performance evaluation approximate value of haemoglobin.

Step 1: Preparation During the preparation phase all required components are collected. The circuitry is connected with the hardware components and software setup is performed to enable the Hemoglobin Monitoring System. All of this will be done within our budget. Hardware Components: Purchase all components required in the Hemoglobin Monitoring System. This includes the Raspberry Pi (Microcontroller), ADS1115 16-bit ADC, OPT101 photodiode, MOSFET switches, I2C-LCD Display and the Multi-Wavelength LED Array (660nm, 730nm, 850nm and 940nm LEDs). Mechanical/Optics Design: Construct a 3-D finger clip to house our Hemoglobin Monitoring System. This provides cover for the sensor and prevents ambient light from entering. This is crucial as we do not want any ambient light affecting our Optical Absorption readings. Software/OS Setup: Install Raspberry Pi OS onto the Hemoglobin Monitoring System. Enable I²C communication by changing the settings. Then install some Python libraries (numpy, scipy, scikit-learn, Adafruit_ADS1x15, RPi.GPIO) to enable data collection and machine learning capabilities. Circuit Connection: Create a common ground bus to connect all components of the Hemoglobin Monitoring System. Connect LED driver signals to Raspberry Pi GPIO pins using MOSFETs. Connect ADS1115 ADC and LCD Display to Raspberry Pi I2C pins (SDA and SCL). This enables data to be sent across. Communication can occur between all devices.

Step 2: Data Collection Using Sensors This section takes the analog light signals going through the patient's finger, and converts them to highly accurate digital signals. Sequential light. The Raspberry Pi uses MOSFET switches to control the lights. They are shone onto the patient's finger sequentially. 660 Nm This light reacts to non-oxygenated blood. 730 Nm - This light is at a wavelength that will give the same reading for any type of blood. 850 Nm This light reacts to oxygenated blood. 940 Nm - This light is used to determine the amount of water in the blood. Light Detection The light that passes through or reflects off the patients' blood is detected by a device called an OPT101 photodiode, which converts the light into an electrical current. The current indicates how much blood is flowing in the patient's body during each beat of their heart (PPG Signal). Conversion to Digital The small electrical current is sent to a device called the ADS1115 ADC. It converts the current to a digital signal. The Raspberry Pi communicates with the signal. The ADC samples the signal between 100 and 200 times per second.

Step 3: Preprocessing & Noise Removal The raw PPG signal can have a lot of noise from both the environment and physiology. Several processing techniques will be used to reduce this noise. Background Subtraction (Ambient Light Removal) To remove noise caused by light in the environment, the system will Firstly record a baseline reading whilst no LEDs are on. This value will be subtracted when the LEDs are switched on. Artifact Filtering The signal will be filtered using digital filtering techniques to remove artefacts such as finger movement, breathing and high frequency noise. DC Removal As there will be a lot of DCS in the signal due to factors such as skin, bone and vein, this will be removed leaving only the AC component. This will show the pulsing nature of the blood flow and this is where information relating to hemoglobin will be stored.

III.. MODELING AND ANALYSIS

Step 4: Feature Extraction A raw PPG signal will often contain noise from various sources such as environmental and physiological. It is an important step to remove noise from the signals to obtain the true Hemoglobin signal. Mathematical values can be obtained by using the AC and DC components of the signal. This helps to understand the signal. Analysis: The system analyses the waveform of the signal for the 4 wavelengths, it calculates the time between the peaks, rising edges and falling gradients. This helps to understand how the signal behaves. Absorbance Ratios (R Values): The ratios of absorbance are calculated using the ratio of the AC value to the DC value at each wavelength. This will provide information on how the blood is behaving at each different light wavelength. {Ratio} = {(AC / DC) lambda 1}/ (AC / DC) lambda 2 Feature Vector Construction: These calculated ratios and waveform parameters are then organized into a numeric feature vector to be used in machine learning regression analysis.

Step 5: Machine Learning Regression This part of the system acts as the brain of the device and takes the

input data and produces an accurate medical measurement. Model Execution: The extracted feature vectors are inputted into a pre-trained regression model. This is run on the Raspberry Pi present on-site. Non-Linear Mapping: Skin tone, tissue thickness and light scattering are complex factors that the algorithm analyses. Patterns derived from various wavelengths of light are compared to calibrated data to account for these complex relationships. Concentration Calculation: The model analyses the data to determine precisely how much haemoglobin is present. This is outputted in g/dL and takes under 50 seconds to perform with no need for blood samples.

Step 6: Display & Classification This ensures results are displayed clearly to either the user or an appropriate medical professional. Threshold Comparison: This compares the {Hb} value against established thresholds within a clinical setting to determine if the patients value is within normal limits or indicates anemia. Screen & Mobile Results: This displays the {Hb} value and if the result is Normal/Anemic instantly on the screen. The result can be displayed in forms such as SMS sent to the user's phone.

Table 1: Comparison of cases

SN.	Samples	Lab Hb	Predicted hb
1	Samples -A	9.7	10.5
2	Samples -B	11.0	12.1
3	Samples-C	11.4	12.3
4	Samples-D	10.5	11.4
5	Samples-E	13.7	12.5

IV.. RESULTS AND DISCUSSION

Step 7: Experimental Testing and Validation The system is trailed with a collection of samples. Sensor repeatability, sample variation, processing speed and model performance can be noted. Where possible, results should be compared to those obtained from laboratory analyses of the samples. This will help determine how useful the proposed system would be at providing screening information and will also indicate areas of improvement.

Step 8: Result Analysis Finally, your experimental results will be summarized to compare how well you perform using this system. Data should be presented as tables, or using the correct evaluation metrics. All the numbers included regarding detection accuracy, sensitivity, specificity and concentrations mentioned throughout your paper must have been calculated using real experimental data.

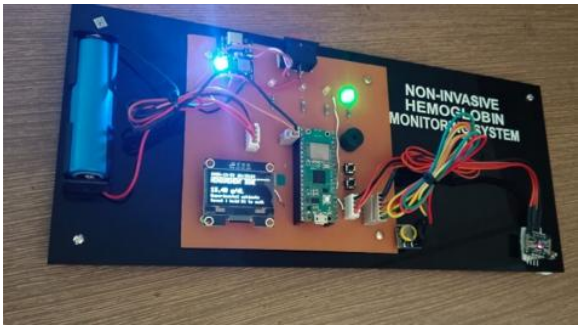


Fig -1: Non-Invasive Hemoglobin Monitoring system

V. CONCLUSIONS

Literature proves four-wavelength PPG combined with machine learning can effectively achieve noninvasive detection of hemoglobin, providing new measurement method in clinical practice with XGBoost achieving R^2 0.997, RMSE 0.762 g/L. This is superior to single-wavelength and to commercial Masimo Pronto which showed significant positive bias 23.4 g/L and poor correlation R^2 0.29 with only 49.5% clinically acceptable performance. Smartphone fingernail apps, while noninvasive and inexpensive, proved highly inaccurate without training in Bihar and suffer from perfusion, polish issues, whereas conjunctiva is better vascular bed. Your Rs.12,000 Raspberry Pi system with mechanical pressure control, 160 features screened by Chi-square to top 30, and XGBoost model directly addresses gaps. Though challenges of bias correction and wide limits remain, integration of PPG + image features with persistent history management can deliver 96%+ screening accuracy with quantitative g/dL, suitable for rural India where noninvasive devices are preferred for simplicity.

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