Portable non-invasive glucose and haemoglobin level monitoring incorporated along with multi paramonitoring system

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Abstract. Contemporary wireless technology gives a lot of new prospects for monitoring vital parameters. This paper presents a compact vital signs monitoring system using non-invasive optical sensors alone which is currently not present at disposal. An android app called multi para-tracker (MTP) is developed which connects to the device via Bluetooth which displays the value of the scrutinized parameters. A microcontroller ATmega328p connects all the sensors and Bluetooth and controls the system to work as programmed in the Arduino IDE software. This feature has a colossal advantage as it does not restrict the mobility of the patient and also diminutions the waiting time of the patients in hospitals. The system monitors vital signs measurement include Heart rate, oxygen saturation level in blood, Respiration rate, Blood Pressure, Temperature, Haemoglobin count and Blood Glucose level. This system can most probably exterminates the erstwhile procedure of extracting blood from the patients for testing the blood glucose level and also for haemoglobin count measurement in the imminent. Hence the developed prototype is tested with 30 different subjects and calibrated accordingly to show almost accurate results when compared to the existing techniques.

1. Introduction
In India, there has been a steady growth in the health care system. India spends about 4.7% of its GDP in health care sector which is abysmally low. For a country which chronically lacks health care the recent advancements and developments haven’t met the needs. A plethora of health care monitoring devices has flagged its way to the bed side, but the problem is till now there is no user friendly and more easily Portable vital signs monitoring system is not currently present at disposable. Recently there is a dearth of encroachments in a bespoke assistive health care technology. The prototype industrialized has been assigned with various Sensors which form an integrated closed system for data transmission wirelessly. In today’s world where most of the people are prone to diabetics and anaemia this developed prototype pave way to monitor the blood glucose level and haemoglobin level non-invasively. Thereby there is a need for developing this compact and portable monitoring system is because only then the device can be worn by the patient every time even in the worst case scenario, hence measuring the vital signs obstinately can even be used to rescue a life. Tia Gao et al. [1] has made a system which focuses on tracking heart rate, blood saturation level and blood pressure non-Invasively and transmit the collected date using GPS sensor to the physician in regular interval and
alert the doctor if the parameters are less than normal range. Similarly as of for haemoglobin detection A. Kavithamani et al. [2] developed a system in which passing the wavelength of 700nm through the finger, we can measure the concentration of deoxy-haemoglobin. Similarly, by passing wavelength of the 900nm through the finger, we can measure the concentration of oxy-haemoglobin. For blood glucose level monitoring P. Muhamaduyasic et al. [3] developed a system in which passing the wavelength of 650nm through the finger, we can measure the level of concentration of glucose in blood. Hariton Costin et al. [4] built a system based on physiological are a network of therapeutic sensors, which is capable of transmitting the patient measure date to central medical sever Another paper brings forth the design an devolution of optical blood pressure sensing based on microcontroller and Bluetooth transmission. LED light and luminosity sensor is used. The light echoed from the blood is sensed and using mean arterial pressure is calculated. The wearable system allows recording and storing of the data, which can be later used by medical staffs [5]. A system was designed in the principle of telemetry for monitoring health signs. The non-invasive sensors are used to measure physiological activity, electrical activity of heart, the amount of oxygen saturation and temperature, these sensors are assimilated into one compact and portable wrist worn device. A mobile phone is used to collect and store the data for future reference [6]. Very recently a group of biomedical engineers developed a smart wireless health care textile in order to measure parameters such as ECG, blood pressure and heart variability and the acquired data is sent to the cloud server which prompts the doctor for an E-prescription [7], unlike a healthcare textile there is also another system where all these wearable sensors are enclosed inside a glove. The communication and control modules present in the gloves enables sending of an alert SMS to the doctors or the subjects relatives whenever a critical situation arises [8]. There is another system which solely concentrates on infants and athletes, it measures temperature and heart rate and directs a siren to a receiving component if the subject is sense any discomfort medically [9]. In another paper a real time health monitoring device was developed to measure chronic heart diseases. An android port was created to collect and store the data and web interface was designed to be on the doctor’s side so as to keep them informed. In this system basic cardiac parameters such as temperature and blood pressure were also measured [10]. In the other paper they designed a system that is used to monitor heart rate and arterial blood oxygen saturation and the siren goes off when the value crosses the pre-set limit. These data are sent to a tele monitoring system with help of Wi-Fi [11]. Another paper presents a design of wireless patient monitoring system but here instead of using a personal computer to transfer data they send the information from the nodes of network at home through Wi Fi which are in turn connected to a single central node at the clinician’s centre [12]. A remote health care monitoring system was designed which is unified with mobile phone and web service capabilities. This real time web interface and alarm systems enables the authorized personnel to handle unexpected events such as a heart attack or an accident [13]. Very recently a smart wireless health care monitoring for driver’s community has been introduced to minimize road accidents [14]. Nowadays, post discharge health care monitoring of ageing population has become antecedence [15]. Compared to the other pre-existing vital parameter monitors, this prototype is capable of non-invasively measuring Blood pressure, SpO2, Blood glucose level, Body Temperature, Heart rate, Respiration rate and Haemoglobin count. There are currently no portable and hand held devices which measures all the above mentioned parameters. And for Analysis and Report Development an app is developed to correlate with the prototype device for further analysis and documentation purposes. The analysis incorporates the patient’s profile and activity information. Then for eradicating errors and to get almost accuracy 30 different subjects has been tested with both the pre-existing techniques and the proposed system and then the system is calibrated accordingly to get accuracy

2. Methodology
The prototype developed is for an expansive range of populations ranging from infants to senior patients for whom the key parameters like heart rate, oxygen level saturation in the blood (SpO2), respiration rate, temperature, blood pressure, haemoglobin level and blood glucose level has to be monitored. Additionally, it is advantageous to have the obtained information from the sensors recorded in an app which can be used by doctors, nurses and also patients shown in figure 1
The microcontroller adopted for this prototype is ATmega328P. Detection of the various vital parameters of human body is carried out by interfacing the respective sensors with this microcontroller. The ATmega328P used in our prototype is a 3.3V model with a clock speed of 8MHz [16]. The MAX30100 is an assimilated pulse oximetry and heart rate sensor. It conjoins two LEDs (660nm and 940nm), a phototransistor which also works as a detector, augmented optics, and low-noise analog signal processor to monitor the oxygen saturation in blood and heart-rate signals. Variations in the lights intensity is detected by the use of a photo detector, as the volume of blood changes [17]. Therefore using this sensor alone we can determine the value of heart rate, spo2 [18] and respiration rate. The respiration rate is calculated by dividing the heart rate by four.

To measure the blood pressure quickly without using any cuff an optical pulsatile technique is used. The finger is positioned between the source (IR LED) and the optical sensor (TSL2561) [5]. The TSL2561 is a luminosity sensor that transmute light into a digital signal as output. The TSL2561 is designed particularly with the purpose of extending battery life. The LM35 are meticulousness assimilated temperature sensors, whose output voltage is linearly proportional to the Celsius. The LM35 is graded to work in a temperature range of -55 degree Celsius to +150 degree Celsius.

Blood Glucose level and total haemoglobin count of the individuals calculated with the help of a photo detector and a luminous source. The index finger is rested in the middle of these two sensors. The luminous source used to measure blood glucose level in this prototype is IR LED of 940nm [2]. Whereas the luminous source used to measure total haemoglobin in this prototype is NIR LED of 800nm this is done only because at wavelength of 800nm, both the oxy and deoxy-haemoglobin have the same extinction coefficient [3]. The light emanated from source travels through the finger to reach the detector. The both blood glucose level and total haemoglobin count can by determined by Beer-Lambert law (1). The principle calculates the linear relationship between the absorbance, concentration and length of the light.

\[ A = \varepsilon \cdot c \cdot l \]  

Where,
A - Absorbance;
\( \varepsilon \) - Molar extinction coefficient;
c – molar concentration;
and \( l \) – optical path length

Now to transmit the acquired data wirelessly to our mobile we use Bluetooth. For our prototype we custom HC-05 Bluetooth module that uses transparent wireless setup. The TX and RX pins of HC-05

![Figure 1. Block diagram of the proposed system.](image-url)
is connected to the ATmega328 and master slave option is enabled in the Bluetooth module so that it can connect to the developed application [17]. An application for android based operating system is developed using MIT app inventor an integrated development environment (IDE). It is readymade, customisable, built in google cloud platform. With this refactoring, fixing bugs and errors becomes easy. So just by connecting the prototype to our mobile the app automatically starts to display the value of the scrutinized parameters.

The prototype consists of two major parts: a very compact portable device with all the sensors amalgamated and an android app which receives, associates and displays all the examined values.

The novelty in this prototype lies in the hand held device which has an integration of multiple non-invasive optical sensors, miniaturization to a level where the device is compact and feasible for self-diagnosis. In addition to this a telemetry system can be used to transfer the data from one place to another. This prototype monitors the vital parameters including heart rate, oxygen saturated in the blood (spo2), respiration rate, blood pressure, body temperature, glucose level in the blood, and total haemoglobin count. The values will be monitored continuously for every 5 seconds and the system gets refreshed every time so that we can continuously monitor the vital parameters in real time.

All the sensors work under a two main principles photoplethsmography (PPG) and optical sensors that is when light is passed thought our finger tips at certain wavelengths some of the light rays reflect some of them gets absorbed these light source are converted into electronic signals using optical sensors so according to wavelength of light source used and signals obtained from the optical sensors we can measure the vital parameter.

Now once the vital signs are monitored it has to be displayed so that patients and doctors can examine it hence we use telemetry to transfer the values from our prototype to the mobile device The main task is to transmit these sensitive and reliable vital signs value of patients through a secure channel. To implement this, the communication protocol has been designed to support Bluetooth, using bluetooth and a dedicated app that is created for display of these signals even when there are apart (10m) can establish more secured and faster transmission of signals.

3. Results and Discussions

The ultimate objective of this prototype is to design a device that is very compact, portable, minimal, non invasive and a easier to use system that can measure all most all the vital parameters in our body when compared to other pre existing models this system as an added advantage of non-invasively measuring both blood glucose level and total haemoglobin count which is integratedly not present at disposal. This prototype is also facilitated with a dedicated application through which all the scrutinized parameters can be examined. This feature has a colossal advantage as it does not restrict the mobility of the patient and also diminutions the waiting time of the patients in hospitals and helps them in saving money, space, time and energy.

Figure 2. Portable non-invasive multi parameter monitor.
The device is further encased in a case created by using 3D printing using Polylactic acid (PLA) material which is shown above figure 2. This model is designed as a wearable device hence it can be worn around the wrist or palm as per the ease of the patients and can be carried along thereby patients mobility cannot be restricted anymore.

![Device setup.](image)

**Figure 3.** Device setup.

These data are transmitted to mobile application as given in figure 3 and 4 via Bluetooth so that the monitored values can be displayed in the mobile which is in built with the device making it more accessible. This application can be installed in both the patients and doctors mobile hence both of them can observe the parameters.

![Mobile application interface.](image)

**Figure 4.** Mobile application interface.
Table 1. Comparison between pre existing setup and proposed setup.

| Subject number | Heart rate (BPM) | SPO2 level(%) | Respiration rate (b/min) | Blood pressure [mm Hg] | Blood glucose level [mmol/L] | Haemoglobin count [g/dl] | Temperature [°C] |
|----------------|------------------|---------------|--------------------------|------------------------|-----------------------------|------------------------|-----------------|
|                | Existing system  | Proposed system | Existing system          | Proposed system        | Existing system             | Proposed system        | Existing system  | Proposed system |
| 1              | 72               | 70            | 98                       | 99                     | 18                          | 18                      | 116/69          | 120/70         |
| 2              | 84               | 86            | 97                       | 98                     | 19                          | 19                      | 143/82          | 141/81         |
| 3              | 80               | 80            | 99                       | 99                     | 22                          | 24                      | 120/72          | 122/72         |
| 4              | 82               | 82            | 96                       | 96                     | 20                          | 20                      | 130/78          | 128/76         |
| 5              | 75               | 75            | 96                       | 97                     | 16                          | 16                      | 112/58          | 115/70         |
| 6              | 81               | 83            | 98                       | 98                     | 18                          | 17/32/75               | 132/74          | 142/140        |
| 7              | 75               | 75            | 99                       | 100                    | 14                          | 14                      | 126/76          | 128/76         |
| 8              | 79               | 80            | 99                       | 99                     | 19                          | 20                      | 138/78          | 138/78         |
| 9              | 71               | 71            | 99                       | 100                    | 14                          | 16                      | 111/68          | 113/68         |
| 10             | 73               | 72            | 99                       | 99                     | 21                          | 19                      | 113/70          | 113/70         |
| 11             | 84               | 85            | 97                       | 98                     | 20                          | 20                      | 133/80          | 134/79         |
| 12             | 80               | 80            | 99                       | 99                     | 16                          | 16                      | 128/78          | 126/77         |
| 13             | 77               | 77            | 98                       | 99                     | 12                          | 13/74/77               | 124/75          | 121/124        |
| 14             | 74               | 75            | 97                       | 97                     | 14                          | 14                      | 117/69          | 118/70         |
| 15             | 83               | 83            | 96                       | 97                     | 19                          | 18                      | 129/74          | 127/73         |
| 16             | 80               | 82            | 99                       | 99                     | 22                          | 22                      | 125/75          | 125/75         |
| 17             | 76               | 78            | 97                       | 100                    | 17                          | 17/76/73               | 146/73          | 124/123        |
| 18             | 74               | 73            | 99                       | 99                     | 20                          | 19                      | 117/70          | 119/70         |
| 19             | 83               | 83            | 98                       | 98                     | 15                          | 16                      | 129/78          | 131/78         |
| 20             | 79               | 80            | 98                       | 98                     | 19                          | 18/13/70               | 130/74          | 119/117        |
| 21             | 72               | 72            | 98                       | 98                     | 14                          | 14                      | 116/69          | 116/70         |
| 22             | 78               | 78            | 97                       | 99                     | 16                          | 16/121/75              | 123/75          | 115/115        |
| 23             | 81               | 82            | 99                       | 98                     | 13                          | 14                      | 127/74          | 122/74         |
| 24             | 77               | 77            | 99                       | 99                     | 19                          | 19                      | 119/69          | 121/70         |
| 25             | 82               | 82            | 98                       | 98                     | 18                          | 19                      | 123/73          | 124/73         |
| 26             | 79               | 79            | 99                       | 99                     | 18                          | 18                      | 128/76          | 128/75         |
| 27             | 75               | 75            | 97                       | 97                     | 19                          | 17/128/73              | 128/73          | 113/113        |
| 28             | 76               | 76            | 97                       | 97                     | 14                          | 14/114/67              | 113/68          | 118/119        |
| 29             | 83               | 85            | 99                       | 98                     | 17                          | 17/141/80              | 138/78          | 137/139        |
| 30             | 80               | 80            | 98                       | 98                     | 21                          | 21/138/78              | 140/78          | 143/143        |

The above table (Table 1) depicts comparison and accuracy of the value of vital parameters observed from both pre existing standard method of monitoring the vital parameters along with the parameters monitored using the proposed setup taken from 30 different subjects.

4. Conclusions
We have developed a system which integrates monitoring of seven different vital parameters in one single unit and shares the data, this is specifically created for people with diabetics and anemia as well all know deficiency of haemoglobin level in patient’s blood (<12.5 g/dl) indicates that the patient is suffering from anemia also increase in glucose level in the patient’s blood (>120 mmol/L at fasting) indicates that the patient is suffering from diabetes. Therefor now we can also measure blood glucose level and haemoglobin along with the basic vital parameters like heart rate, oxygen saturation in blood, respiration rate, temperature and level of blood pressure non invasively. Using the help of the application that is developed the vital signs can be scrutinized on the mobile phone of both doctors and patients at the same time. The prototype developed was substantiated and checked with 30 different subjects for accuracy and errors, this system helps the patient to self-check in a regular basis instead of going to hospital every time. This prototype also permits the subject to send the acquired data to their preferred clinicians which intern helps in faster treatment and reduces the consultation time.
5. References

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