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Low cost Pulse Oximeter with Smartphone Connectivity

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ABSTRACT: Oxygen is an essential source of living for all of us. This oxygen is utilized by each and every part of the body as it is absorbed by the arterial blood and travels in each and every cell of the body. If this blood oxygen levels get dropped, it would become an extremely severe condition for a person. In the present research, a system is designed that can measure these vital signs of body i.e. blood oxygen saturation levels (SpO_2) and pulse rate of the person in a cheap and efficient way. The designed system provides a connection of the system with the smartphone so that the measurements can be read accurately and stored and shared in a profound way. The designed device is figure adjustable and does not allow surrounding lights to get through it. The designed device is compared with the commercially available device and found to be very accurate with the measurements of commercially available device for the measurements of designed device.

KEYWORDS: Cost-efficient, Oxygen saturation, Pulse rate / heart rate, Pulse-oximetry, Smartphone.

INTRODUCTION

In the present times, advancements of the health-care devices for people in each health-care sector is increasing day by day. In continuation to this linage of advancements, improvements in domestic health-care devices are also increasing significantly. Most of these domestic devices measures heart-rate, blood-pressure, temperature, etc. Among most of these devices, pulse oximeter is one such domestic health care device that is utilized to measure the oxygen saturation present in the person's blood noninvasively. Pulse oximeter are significant in detecting early symptoms of heart rates. Also, when the oxygen saturation of the person's body decreases from the standard values, then he/she is given oxygen externally, in order to stabilize the SpO_2 values.

A convenient and non-invasive procedure used to analyze oxygen saturation (SpO_2) in different parts of the body is pulse-oximetry [1]. In order to speed up weaning via mechanical ventilation and extubation, the use of pulse oximetry is efficient and decreases the frequency of bleeding for the examination of arterial blood gases (ABG), since pulse oximetry can be a good choice for patients who only need to keep a check for their O_2 saturation [2], [3]. Other benefits of pulse oximetry are versatile utilization, speed and high precision in hypoxia detection and constant monitoring of patients [3]–[5]. The amount of oxyhemoglobin and deoxygenated hemoglobin in arterial blood is measured by the device and displays it as oxyhemoglobin saturation (SpO_2) that is indirect indicative of the determination of arterial oxygen saturation (SaO_2) [6], [7].

In healthy people, the normal level of SpO_2 is 97 percent to 99 percent [8]. The level of SpO_2 has high precision and is two percent different from the level of SaO_2 obtained by ABG examination, if the SaO_2 is 70 percent to 100 percent [5]. But, the level of pulse oximetry error is recorded as 7.2 percent in more severely ill patients [9]. The precision of the instrument can be influenced by different factors, including physiological, environmental, technological failures and human error [1], [3], [6], [10]–[12].

In the present research a portable, non-invasive model of pulse oximeter is designed that is proficient in computing the person's oxygen saturation levels accurately and whose data can be managed and stored on to the user's smartphone.

Research Questions

- How can a cheap and efficient device for measuring the oxygen saturation and pulse rate of person be made and can be connected by user's smartphone?

Pulse oximetry is a technique that is employed to see the blood oxygen saturation levels (SpO_2) of the person's body and along with heart or pulse rate of the body. A Blood saturation level of a person is a vital level, measured during critical and non-critical conditions and is an indicator of the amount of oxygen in the hemoglobin. These measurements reading are so essential and is been updated with every heartbeat.

The precise detection of SpO_2 by pulse oximeter obtained from the associated studies has conflicting and controversial findings. In their report, John concluded that the forehead pulse oximeter sensor had higher accuracy in SpO_2 detection compared to transitional finger pulse oximetry among patients under vasopressors [13]–[15]. The principle of pulse oximeter is dependent on the absorption of red light (of wavelength approximately 650 nm) by the deoxygenated blood and the infrared light (of wavelength approximately 950 nm) by the oxygenated blood. In addition, it is possible to measure the heart rate from the subtle change in colour caused by a pulse that drives arterial blood into the finger [16].

The pulse oximetry have become a standard practice in various reputed and chain hospitals. Although, this standard is in practice with many government hospitals but most of the public health care centers across the country are deficit with this standard as they do not have devices to measure the blood saturation levels as because of their high cost [17] [18]. In order to overcome this problem, the present research has been in the direction of designing low-cost pulse oximeters.

Although, there might be the matters regarding the availability of pulse oximeters, but even though if there is a pulse oximeter available, then also there might be the probabilities that device to server or server to device communication may not be there, which eventually restricts the user's continuous monitoring for the pulse oximetry data. Moreover, if there may the possibilities regarding the established communication, then there are the likelihoods that adheres the user concerning device management functions. In order to cope up with these issues concerning communication and cost, the present study shows and developed the design of the a cost-effective device, equipped with wireless communication capabilities [19]–[21] that enables the user for continuous monitoring for his vitals.

In the present research the usage of internet of things (IoT) has played a major role. The IoT stands alone as a master controller for all the operations [22], [23]. IoT manages the device to server and server to device communication efficiently and with its application, it enables the device to perform all the necessary pulse oximeter operations according to the user.

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METHODOLOGY

1. *Design of the experiment:*

The design of the experiment to manufacture a device that can be utilized to compute the blood oxygen saturation levels of a person. The components for manufacturing the required device have been listed below in the instrument section. The device is designed in a way that it can be adjusted to the tip of the person's figure so that it can submerged inside device and can block the surrounding lights (if any). The role of light is pivotal in the present research as the present experiment is based on different wavelengths and absorption levels of the light along with their detection. The lights utilized in the present research are red light LED and infrared LED. The chosen lights have different wavelengths i.e. for red length it's around 620 to 750 nm and for infrared light it's about 800 nm to 999 nm. These different wavelengths of lights have been selected as they are important in detecting the oxygen saturation in blood.

The blood has hemoglobin and is in the combination of oxygenated blood and deoxygenated blood. The tendency to get absorbed into oxygenated blood is shown more by infrared light than red light and the tendency of getting absorbed more in deoxygenated blood is shown more by red light than infrared light. Making this as a principle of the study, the device is designed in a way that it has both the red and infrared LEDs present on the top and for detecting the intensities, wavelength, path, and absorption of these two lights by the blood inside the finger, a photo-detector is placed on the base of the device.

The device is designed in such a way that it can be adjusted for a finger in vertical motion so that the possibility of detecting surrounding lights by the device's photo-detector could be minimized. The device is connected by the smartphone via bluetooth and the readings of blood saturation levels of a person along with their pulse rate or heart rate and relation between absorption and time of their blood can be seen on the smartphone. There is also a display present on the device for immediate displaying these parameters.

The designed device has a micro-controller that is programmed in such a way that it can perform all the calculations of subtracting the absorption of light by figure-tissues, and surrounding lights (if any) from the total of the absorbance of the lights to get the accurate absorbance of the lights by the oxygenated and deoxygenated blood. The device is also calibrated by a normal pulse-oximeter from the market and in persons' test to gain high accuracy. The representation of the designed device can be seen in Figure 1.

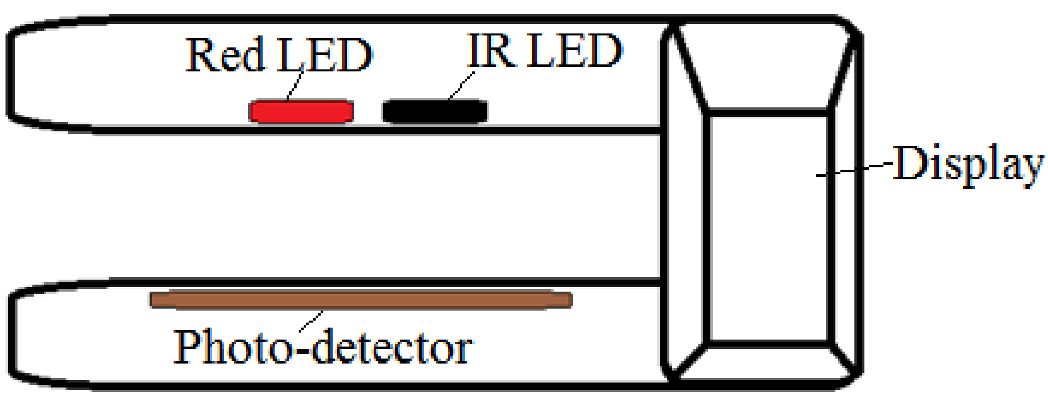

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Figure 1: Representation of the designed device.

2. *Sample:*

The tip of the person's figure from where the oxygen saturation is measured is the sample of the present study.

3. *Instrument:*

The instruments used in the present study are listed below with their representation in Figure 2.

- Red LEDs.
- Infrared LEDs.
- Photo-detector.
- Bluetooth
- Display
- Arduino

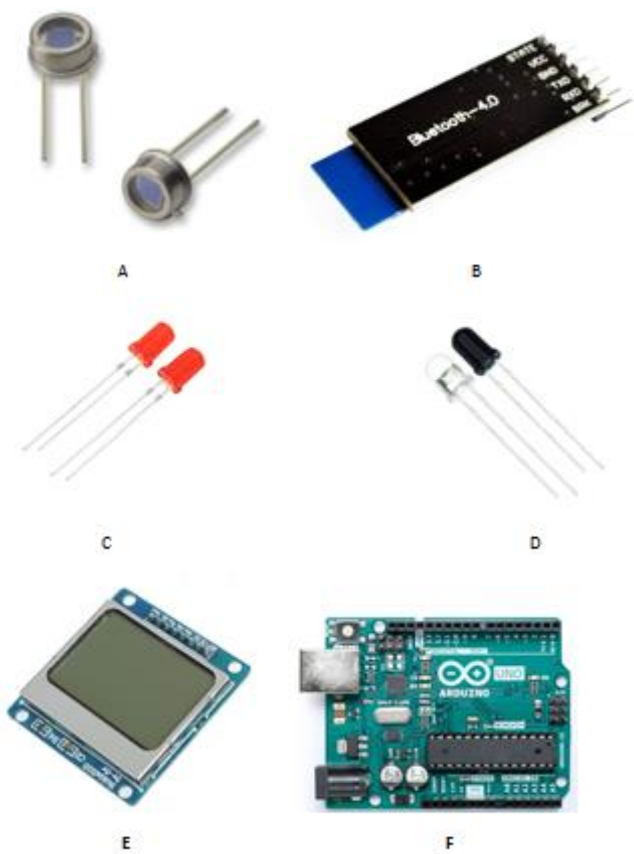

Figure 2: A-Photo Diode, B-Bluetooth, C-Red LED, D-Infrared LED, E-Display, F-Arduino.

4. *Data collection:*

The data collected of different patients utilizing the device is given in Table 1.

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Table 1: The readings of different patients that have been measured by the designed device

Parameter	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
SpO_2 level	100 %	95 %	97 %	97 %	94 %
Pulse rate	93 bpm	109 bpm	89 bpm	127 bpm	102 bpm
Device Display	Working	Working	Working	Working	Working
Smartphone's readings	Same as Device's display	Same as Device's display	Same as Device's display	Same as Device's display	Same as Device's display
Red LED indicator	Working	Working	Working	Working	Working
Infrared LED indicator	Working	Working	Working	Working	Working
Actual SpO_2 levels by market pulse-oximeter	102%	96 %	99 %	97 %	95 %
Actual Pulse rate by market pulse-oximeter	95 bpm	114 bpm	92 bpm	125 bpm	108 bpm

5. *Data analysis:*

The saturated oxygen levels of different patients along with their heart rate or pulse rate have been measured by the designed device. The measurements were collected and further with commercially available pulse oximeter, the oxygen saturation and heart rate were measured again for the same patients, whose parameters were measured by the designed patient in a gap of one or two minutes.

The measured values of the designed systems were compared with the values of commercially available pulse oximeter for the same patients and found a minute/ little or negligible difference in their readings for oxygen saturation and pulse rate.

RESULTS & DISCUSSION

In Figure 3 and Figure 4, plot of SpO_2 levels and plot of pulse rate between designed system and commercially available system of pulse-oximeter is presented respectively. The measurements of readings for oxygen saturation and pulse rate were done with five different patients and readings were compared again with the commercially available pulse oximeter of the same five patients within 1-2 minutes for determining the accuracy of the designed system.

The accuracy levels of the designed system approximately gained up to the accuracy level of the commercially available device of pulse oximetry. The device made is very cheap and can be added features accordingly. The device is connected via smartphone through bluetooth so that the values of heart rate and oxygen saturation levels of the person can be seen directly on the smartphone and can be shared further.

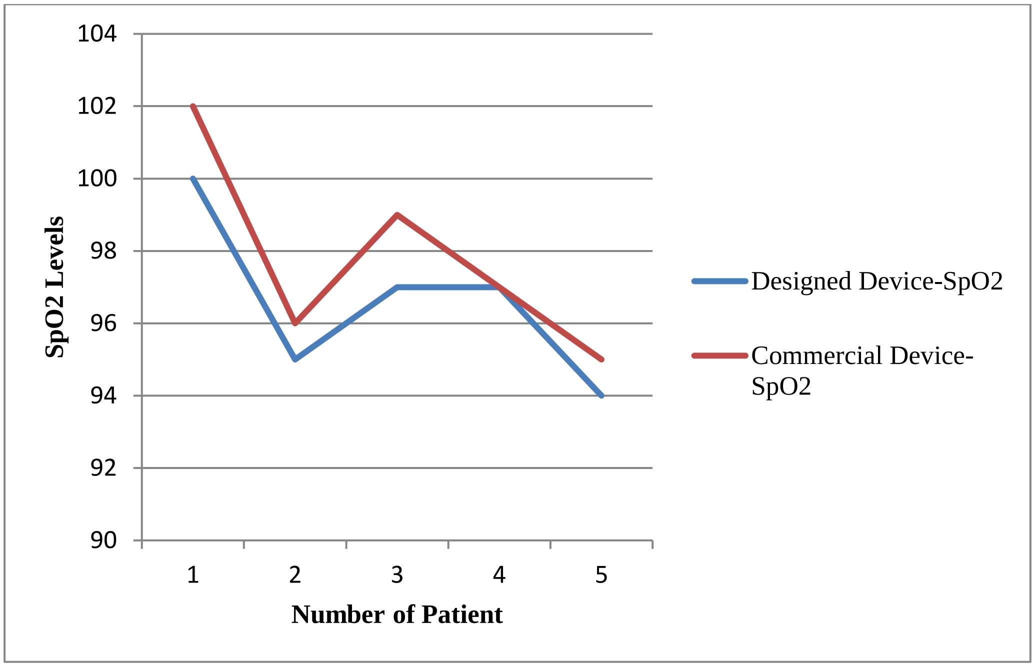

Figure 3: The plot between SpO_2 levels of the designed system and commercially available system.

Figure 4: The plot between pulse rate of the designed system and commercially available system.

CONCLUSION

A device is designed that is utilized to measure blood oxygen saturation (SpO_2) levels along with heart rate/ pulse rate of a person at low cost and is efficiently accurate. This device can be utilized domestically by any person who wants to see their oxygen saturation levels and pulse rate accurately. The device is easy to operate and can be adjusted according to the size of the person's figure with figure adjustment mechanism. The device is designed that no extra surrounding lights can enter in the device to give it maximum level of accuracy. The designed system can be further utilized to add certain non-invasive body parameters such as blood pressure measurements, etc. The device can be utilized majorly at primary health care centers and can be made available on a cheap basis so that individualized oxygen saturation level (SpO_2) and heart rate level measurement can be made for the marginalized society as well.

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