Smart Multifunctional Vital Testing Kit for Patients

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***Abstract*—The coronavirus or Covid 19 is a highly infectious disease which took a huge toll of human lives between the years 2019 and 2021. The global spread of the virus has overwhelmed health systems, and caused widespread social and economic disruption. Strategies in the control of an outbreak are screening, containment and mitigation. The process of collecting and recording vital signs can be a time- consuming process without the right tools. The main motive of the invention disclosed here is the integrated portable healthcare solution that will help in quickly carrying out Covid screening vital test measurements such as temperature, pulse and blood pressure which will not only be used during epidemic/pandemic but also during other emergencies/patient triages and also to keep a track of all affected Covid patient's screening results by the healthcare professionals. Monitoring of vital signs is necessary for the efficient and effective patient management. Vital signs are regularly measured at specific intervals in patients in the Emergency department or remotely.**

This project mainly focuses on the integration of three sensors (i.e.) MAX30100 sensor, MLX sensor and digital BP sensor and producing the values in the same kit. This smart device is used to monitor the person's temperature, blood pressure, SpO2, heart rate and by comparing all the four threshold values, the final result is displayed as normal or abnormal values simultaneously in the mobile app and the LCD display. The system can be used remotely as well in the healthcare setting where patients are in the waiting queue. Based on the results, intimation messages are sent to the concerned patient or healthcare professional who's mobile is linked with the device and in abnormal conditions, the alert message is sent to quarantine themselves from the general public. This continuous monitoring helps in the initial screening for Covid-19 at the early stage, where the results can be checked and timely advices can be given by the family members, doctors and the medical professionals.

***Index Terms*—Covid 19; vital sign; sensors; portable; SpO2.**

I. Introduction

Covid-19 is a severe acute respiratory syndrome caused by corona virus. This disease has outbroken all over the world, and disturbed the normal lives of every individual.In India statistics shows that over 15 million corona cases have been confirmed as of April 18, 2021.Out of these nearly 178,000 cases were fatal. In worldwide, WHO recorded 146,689,258 confirmed Covid-19 cases including 3,102,410 deaths. As Covid-19 is a communicable respiratory disease, isolation from others and monitoring of vital signs of a person is important to know the preliminary heath status of a person. For isolating from infected person or the person in contact with the infected person, general screening test is mandatory. The screening test is done by monitoring the vital signs of a patient. Due to the recent pandemic crisis, a portable multifunctional vital test kit is the need of the hour. There is lso a need to monitor the condition of patients who are waiting in a queue. Although the regular monitoring of vital signs in all patients is essential, it is not always possible because of limited resources (medical staff and equipment). In this paper, we aim to address the research question "How can the healthcare professionals remotely monitor a patient's condition and quickly respond if patient is deteriorating?". The aim of this paper is to design a triage system for inpatients, outpatients, remote patients to assist healthcare providers in patient monitoring and patient management.

The prototype incorporates various sensor integration for data transmission. The developed project mainly pivots on monitoring heart rate, SpO2 level, temperature and BP value of a patient. The values are detected in real time & the collected data can be transmitted through mobile application. As the project is integrated with digital bp sensor, less labor work is required and accurate results can be obtained without environmental disturbances. And in the transfer of data through mobile application, a high-speed internet connectivity and a reliable network is needed because the value transmitted from sensor are of real time tracking. This paper describes remote, efficient and a non-invasive heath care systemwhich can be used for all ages.

II. Technical Review

This section discusses the review of smart vital testing. In the paper [20], the authors describes the non-invasive technologies for measuring blood glucose level and haemoglobin count of patients. It collects some of the body parameters such as heart rate, oxygen level saturation in the blood (SpO2), respiration rate, temperature, blood pressure, haemoglobin level, blood glucose level and the signals are sent to the transmitter and processed through mobile app to provide remote healthcare services.

The system takes advantage of monitoring health of person in generating alert signals in emergencies. This system suffers a major challenge of the volume of information needed to be transmitted due to a large number of sensors, battery usage, privacy and data security. For measuring the body parameters, sensors are used and the collected data is sent through Bluetooth to mobile app which is then assessed and alerts the health care professionals in case of emergencies. This device continuously monitors the blood glucose and hemoglobin along with blood pressure and pulse rate from the beginning. The sensor network is designed such that they do not disturb the normal physiological activity of the person. These parameters can be measured using the minimum number of sensors using [7]. This is almost similar to the proposed method in which only certain parameters are considered for monitoring. The collected data is transmitted using GPS Sensor to the physician in regular intervals.

This prototype in [6] consists of a smartphone placed on the patient's body which detects the heart rate with the help of the accelerometer present in the phone. This is mostly suited for monitoring stationary persons but has a very good accuracy compared to the conventional ECG-derived measurement. There is another system which monitors the hemoglobin and heartbeat of people noninvasively when they mount on a treadmill thereby adjusting the speed automatically to avoid dire conditions. This system mainly focuses on the anemic patients to exercise without any risk on the treadmill [7]. A Zigbee-Based Wearable Physiological Parameters Monitoring System [8] describes the wearable prototype which measures physiological parameters like temperature and heart rate, along with this, impact or fall detection is also monitored. This device gives off a distress alarm when it detects medical discomfort. This is especially suited for athletes, the elderly, and infants.

As in [9], the authors have designed a real-time monitoring system for cardiac patients remotely using smartphones and wearable sensors. They continuously detect the parameters and transmit the same to health care professionals for real-time monitoring so that emergencies can be easily attended. "Multi-parameters wireless shirt for physiological monitoring" paper [10] measures the vital parameters like ECG, heart rate, respiratory rate non-invasively and without any contact by embedding electrodes into the t-shirt thus avoiding the irritation and the need for the gel for the conduction of the signals. These data are then transmitted to the readout device for telemedical consultation. The wearable sensor is also developed using the nanosensor and nanomaterials [11] to help monitor the health of the military, sports, and sick patients. The system in "IoT Based Wearable Smart Health Monitoring System" [12] shows a similar system of measuring body temperature and pulse sensor using Arduino and cloud system. It also sends the alert system to the doctor and family members in case of emergencies. The smart monitoring system in [17] ensures complete monitoring of the patient with three modules namely, a voice recognition system, body sensor network, and emergency module to detect the patient's health in real-time.

Smartwatch sensors [13] are used for the collection of data from the user and transmit the obtained results through Wi-Fi to a healthcare portal where the patient is assessed for their wellbeing. It also supports the alert system which is sent through e-mails. In this paper "Remote Mobile Health Monitoring System Based on Smart Phone and Browser/Server Structure" shows the design of a wearable belt that detects a patient's physiological parameters and transmits the obtained data to a local server. The smartphone acts as an intermediate link. This device consists of a GPS which helps in locating the patient outdoor in case of any emergencies. This device is mainly targeted at the elderly age group [14].

III. System Design & Methodology

A. Design of the system

The parameters like temperature, heart and pulse rate, blood pressure, oxygen level saturation in the blood (SpO2) are usually monitored individually using separate devices like infrared gun thermometer for measuring the temperature and sphygmomanometer for measuring the blood pressure. The integrated vital testing kit that produces quick, accurate and also portable in nature is the need of the hour globally. This kit is basically used to obtain the patient's baseline data for diagnostic and therapeutic purpose. Another main purpose of this kit is to reduce the production of fake kits in the market and ensure the proper availability of vital testing kits. Since this involves a non-invasive method, the risk of infection is avoided. The prototype has main parts, that is a hardware device and a mobile application. The hardware device is a portable one with all the sensors embedded for self-diagnosis and the mobile app collectes and displays all the examined values. This prototype monitors the vital parameters including the heart rate, oxygen saturation in the blood (SpO2), body temperature and blood pressure. The sensors used in this prototype include MAX30100 for measuring heart rate and pulse rate, MLX sensor for measuring the temperature by the concept of infrared spectroscopy and digitalized BP sensor for measuring the blood pressure (shown in Fig 1). The protype has two microcontrollers (ATmega328):one for transmitting and another for receiving the data. The added advantage in this prototype is the use of digitalized BP sensor as it shows accurate values. By comparing the threshold values of heartrate (60-100) beats per minute, oxygen saturation (95-100)%, blood pressure (120/80) mm of Hg, temperature (36-37.1 °C) is considered as normal values. If it exceeds the normal values, the condition becomes abnormal. In case of high blood pressure, it means hypertension and the statistical data showed that patients with high blood pressure suffered the higher risk of Covid-19 infections with severe complications, which is taken into account while designing this prototype. A Wi-Fi module is used to transfer the examined values (vital signs) from the prototype to the mobile device. This helps patients, doctors, and other healthcare assistants to monitor the body parameters in the mobile application itself at specified date and time.

B. Deployment

The Kit deploys three sensors namely; MAX 30100 (Pulse Oximeter), MLX90614 (non-contact infrared thermal sensor), and Wrist Digital BP sensor. These three sensors collect the signals from the Wrist and hands of the patients. The

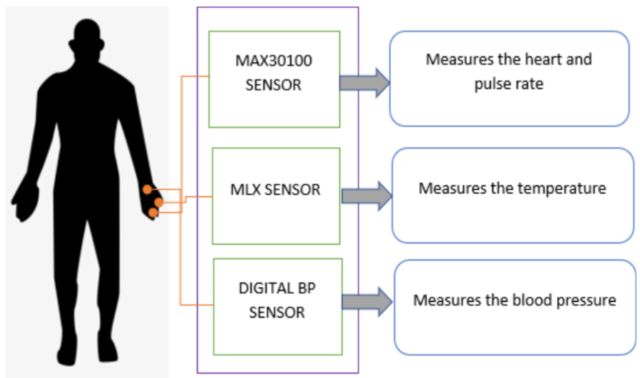

Fig. 1. Integration of sensors with human body.

MAX 30100 sensor is PPG Sensor (Photoplethysmography sensor) which uses light-based technology to measure heart rate (HR) and Blood Oxygen level (SpO2). It is placed on the fingertip and uses the principle of Pulse Oximeter which includes 2 LEDs, one emitting red light(600-670nm), another emitting infrared light(870- 900nm). By detecting the time interval of oxygenated and deoxygenated blood in veins using red light, pulse rate is determined. Depending on the absorption level of both the light sources from oxygenated and deoxygenated blood, the sensor can detect the oxygen levels via the I2C communication protocol. The body temperature sensor (MLX90614) uses non-contact infrared temperature sensing to collect temperature measurements from the finger/ hand of the person close to the surface of the sensor. It is mentioned that detection of the temperature from the hand is more accurate and less harmful than collecting temperature from the forehead as frequent exposure of Infrared rays in the forehead is harmful as in [17]. The Digital BP sensor uses a pressure sensor to measure systolic and diastolic blood pressure non-invasively. For infants, it can be tied around the thigh to measure BP level. Using Oscillometric techniques this Sensor can measure systolic, diastolic, and mean arterial pressure using the wrist cuff. The measured values from the three sensors are displayed on the LCD screen 16 X 2 size and also on the mobile application. The transfer of data from the kit to the mobile application is done by a Wi-Fi module using wireless communications. The obtained values are calibrated to a threshold value. If the values surpass the threshold values, the status of the patient is shown as abnormal in the mobile app, otherwise, it is shown as normal. The overall kit is equipped with batteries and an AC adapter making the kit more portable and reliable (as shown in Fig 2).

C. Methodology

The Sensing Algorithm of the Prototype involved powering the sensors using batteries and placing the sensors in the correct position in the patient's hand (shown in Fig 3). The Wi-Fi module in the kit will search for the device and establish the connection with the mobile app to store and display the

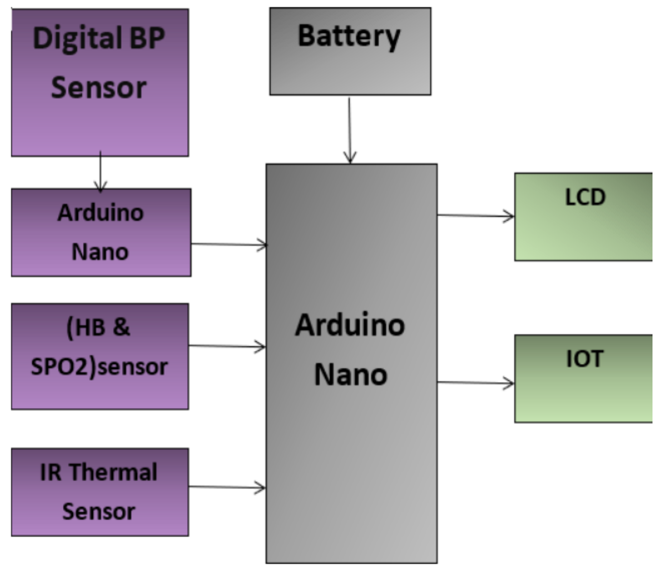

Fig. 2. Block diagram for vital testing kit.

results, Simultaneously the sensors will start the detection of the vital parameters from the patient's body in real-time. These data are obtained from the integrated sensors to obtain Heart Rate, Blood Pressure, Oxygen level, Temperature from the patient's body and send to the microcontroller for the further processing of the data. The Microcontroller will process the vital signal values against the threshold values to determine the patient's condition. The calculated results are shown in real-time in the LCD display and are sent to the cloud for tracking history and future purposes. The results are also displayed in the mobile in real-time which can be sent to the medical professionals/authorities in case of any abnormalities using a GPS to get immediate attention and prevent further complications of the disease.

The developed prototype is focused on a wide range of populations ranging from infants to senior patients measuring vital parameters of the body. Additionally, the obtained information is transferred to the app for future use and diagnosis which can be used by the medical professionals and also the patients to track their health history. All the sensors are integrated into the ATmega328P Microcontroller in this prototype. The Transmitter and Receiver pins of the Wi-Fi module are connected to ATMega328 and values are transmitted from the controller to the mobile application wirelessly.

The mobile application for the android based operating system was developed using Integrated Development Environment (IDE). The MIT app inventor is a customizable, built-in google cloud platform. The developed prototype is connected to the mobile app which will display the values of the scrutinized parameters. The values from the sensors will be monitored continuously every 5 seconds and hence helping to get a compact portable real-time vital monitoring system. The entire prototype is consolidated in two parts namely: A very compact portable sensor network and An Easy-to-Use Mobile App for displaying the examined values. The Vital signals are transmitted in a secure channel by using a communication protocol that has been designed to support Wi-Fi. The system is reliable to transmit the signals from the sensor network to the mobile app, even when they are 20 m apart, ensuring more secured and faster transmission of signals for real-time monitoring. Using fritzing, we show how the microcontroller, sensor and actuators can be connected on a breadboard (Fig 4) and device is setup as shown in Fig 5.

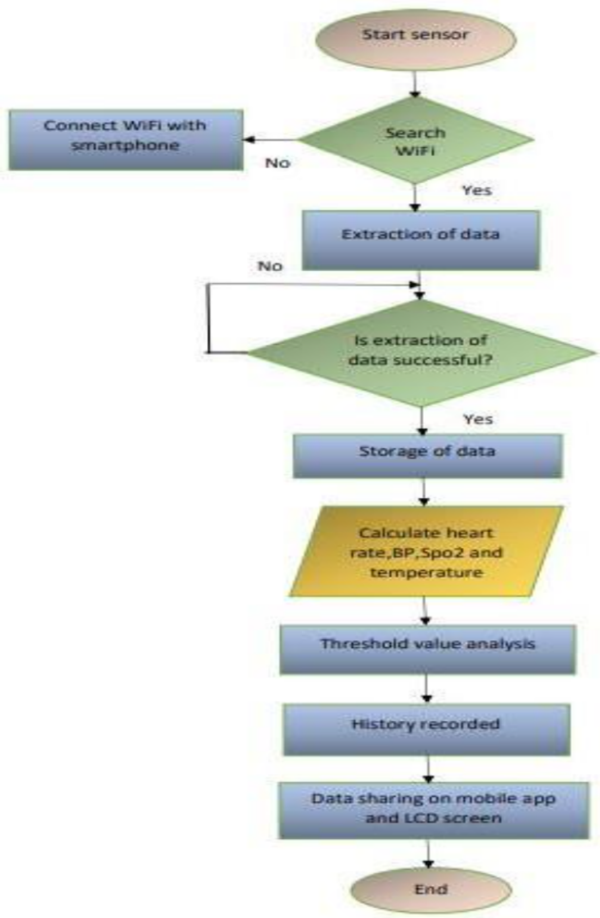

Fig. 3. Sensing algorithm of the prototype.

The self-diagnostic portable integration of non-invasive sensors in this prototype makes it unique, medical-grade accurate, compact and reliable for a general screening kit during this pandemic. Future enhancements to this system may include the transfer of data through a telemetry system for remote monitoring of the patients. The other vital parameters like blood glucose level, respiration rate, and total hemoglobin count can also be obtained from the MAX sensor [18, 19].

IV. Results & Discussions

The system prototype was able to run as expected and we were able to address our research question "How can the healthcare professionals remotely monitor a patient's condition and quickly respond if patient is deteriorating?". The results collected gave vital parameters like blood glucose level, respiration rate, and total hemoglobin count can also be obtained from the MAX sensor [18, 19]. The results collected were able to be displayed not only in the serial monitor and also in the Blynk mobile application and the Firebase Realtime Database. The results in all three were updated simultaneously as shown in Fig 6 ,7 ,8 and 9. Having such a system would ensure a patient is monitored efficiently and effectively. Any changes out of range can be detected quickly and this would enable the health care providers to assist the patient on time. The prototype device is very compact, portable, small and non-invasive and can measure the vital parameters easily. This kit is facilitated with mobile application through which all the heath parameters can be monitored. The data obtained from the sensor are sent to mobile application. The app is designed in such a way that it is easily accessible by all. Thus we addressed the aim by desigingn a triage system for inpatients, outpatients, remote patients to assist healthcare providers in patient monitoring and patient management.

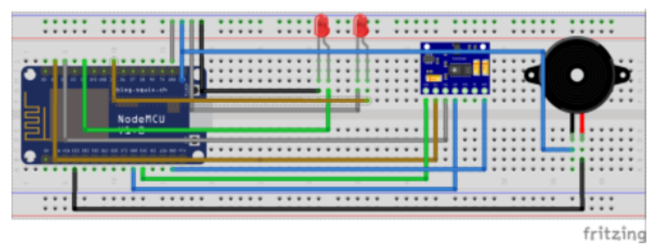

Fig. 4. Fritzing.

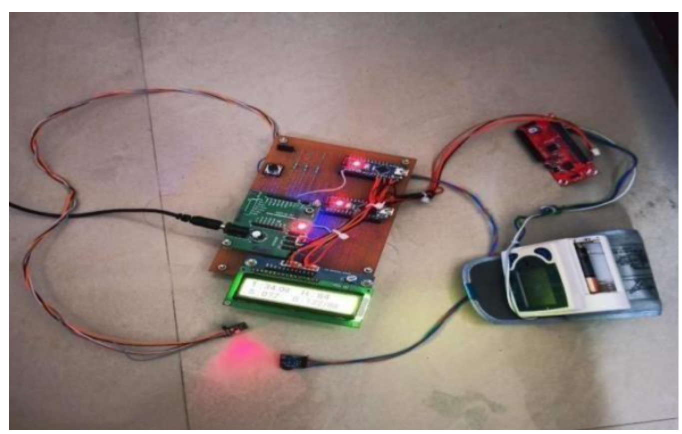

Fig. 5. Device Setup.

V. Conclusion & Future Work

The developed kit is able to detect five parameters namely heartbeat, SpO2 level, temperature and blood (systolic & diastolic). The integrated vital testing kit produces quick, accurate and also portable in nature is the need of the hour globally. This kit is basically used to obtain the patient's baseline data

Fig. 6. LCD Output.

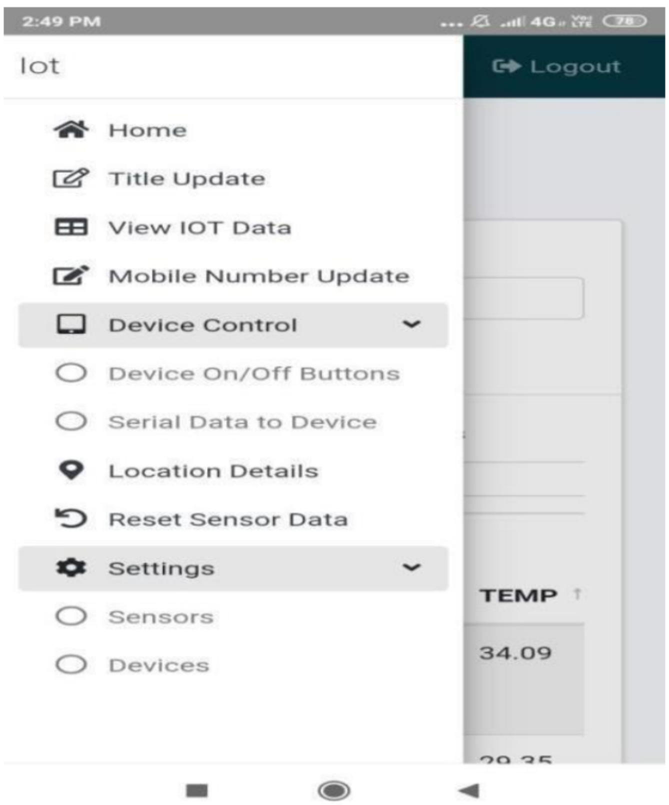

Fig. 7. Home page of the app.

Real Time Sensor Values

Filter By Date 16/03/2021 Find

Show 10 entries Search:

#	HB	SPO2	TEMP	BPS	BPD	Date & Time
1	84	94	34.09	122	89	2021-03-01 13:30:32

Fig. 8. Real time output view 1.

72	90	34.15	150	89	ABNORMAL	2021-04-09 16:46:47
78	92	37.20	128	80	NORMAL	2021-04-09 16:45:15
78	92	38.70	140	100	ABNORMAL	2021-04-09 16:45:11

Fig. 9. Real time output view 2.

for diagnostic and therapeutic purpose. Since this involves a non-invasive method, the risk of infection is avoided. The prototype has main parts, that is a hardware device and a mobile application. The hardware device is a portable one with all the sensors embedded for self-diagnosis and the mobile app collectes and displays all the examined values. This helps patients, doctors, and other healthcare assistants simultaneously to monitor the body parameters in the mobile application itself at specified date and time in a quick and faster way. All these parameters can be monitored in single device and the data is transferred through mobile app, which reduces unnecessary hospital visits for patients by lessening the burden on healthcare systems. The portable non-invasive vital testing kit is not only for covid patients, but also for normal people to keep their vital signs at normal range to maintain a heathy life.

The prototype developed was validated with 25 volunteers for accuracy and errors in the pilot study. Based on the feedback, the volunteers feel the prototype will be of good use to the community in monitoring vital signs of patients. Staff shortages and lack of equipment are some of the reasons that hinder frequent monitoring of patients.

As a recommendation, we believe introducing wearable sensors in hospitals will improve patient monitoring, management and triage tremendously. The use of wearables to monitor vital signs can help prevent sudden death. It would be easy to know through alerts sent by the sensors in the system when a patient's condition is deteriorating. The use of a smart wearable would be beneficial both to health professionals and patients and it would help to monitor the vital signs with ease.

As a future work, we aim to improvise the prototype by focussing on quality, reliability, and speed of transmission using different carriers. As we know, the Internet of Medical Things (IoMT) is an integration of user devices, medical devices, web/mobile applications connecting healthcare servers where privacy and security is the primary key. We will focus on data hacking and data secure transmission by allowing the transfer of medical data over a secure network [15-34]. We will also aim to evaluate the effectiveness and shortfalls of current vital sign monitoring systems in place some of the hospitals, then illustrate the significance of our multifunctional vital sign monitoring in detecting patient deterioration in a hospital setting. The evaluation and questionnaires will not only be focussed from patients' perspectives but also from attenders, doctors and other healthcare professionals point of view, so we can draw more insights.

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