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IoT based Integrated Health Monitoring System

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Abstract

The ageing population worldwide is constantly rising, both in urban and regional areas. There is a need for IoT based integrated health monitoring systems that take care of the health of elderly people without compromising their convenience and preference of staying at home. The cloud as well as IoT (Internet of Things) and the mobile technologies make it easier to monitor the patient's health conditions by sharing the health information to health care teams such as doctors, nurses and specialists. The present work aimed at post discharge health monitoring of a person. SpO2, BP, Heartrate and Temperature are the vital parameters being measured. A module for easy monitoring of patient was developed by acquiring these four key vital parameters. The acquired parameters are stored in ThingSpeak Cloud and displayed on a webpage so that the doctor can easily access the condition of the patient and suggest methods to improve his/her health condition and in case of irregularities suggest hospitalization. The module comprises different sensors to obtain the above-mentioned health parameters and the data is sent to a smartphone using Bluetooth. The data is then uploaded to the cloud from the smartphone and the data can be monitored real-time via the website. The prototype was tested and the deviation between the manual procedure and automated prototype was with in ± 1%.

Keywords:

Intenet of Things;
Bloop Pressure;
Heart rate.

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1. Introduction

Integrated Health Monitoring System (IHMS) is a health care setup that helps the patient to perform his routine tests using mobile health monitoring devices and make the data available to the hospital for monitoring the condition of the patient in real-time. The IHMS consists of monitoring devices like Blood Pressure Monitor, SpO2, Heart rate monitor and Temperature Sensor.

The data collected from the patient using the mobile monitoring devices can be sent to the hospital. The data collected from these devices can be stored in the cloud along with timestamp and which can be used by the doctors for the long-time monitoring of patients' health. There are many ways to send the monitored data of the patients to the health care like sending it using GSM module, Bluetooth, or over the internet using IoT.

Remote health monitoring is becoming one of the major aspects in healthcare industry as the specialist doctors are not available in every part of the world. This project mainly concentrates on the design and implementation of the cost effective integrated remote health monitoring system using cloud storage. The paper from Norhan S Hammed and Mohamed I Owes [1] explains the need for an Integrated Health Monitoring System. Conventional Blood Pressure Measurement involves wearing the device around the upper arm and use of an inflator. This requires the aid of another person. The paper by Simi Susan Thomas, Viswam Nathan, Chengzhi Zong, Karthikeyan Soundarapandian, Xiangrong Shi, Roozbeh Jafari [2] proposes non-invasive wrist-type BP measurement. BP can be measured without the aid of others in this manner. The paper by Karan Mitra and Suguna [3] is an efficient IoT based remote health monitoring system.

In this paper, the fundamental network requirements of a typical remote health monitoring system for real-time event update, data generation and bandwidth requirements are discussed. Also, the network communication protocols such as MQTT, CoAP and HTTP and the bandwidth requirements and the volume of generated data are discussed. Lu Liu, Hongzhou Yu's [4] paper on Remote health monitoring is based on using Zigbee network and GPRS transmission technology. These two technologies are combined to measure the health parameters while the patient is mobile. The data is transmitted through GPRS for long range and through ZigBee for short range. The data output from the health measuring devices are transferred to GPRS gateway. The gateway communicates the data to the concerned person for further analysis. The paper from M. Sajeewani Karunarathne [5] is about the Remote Monitoring System using Cloud Technology upon smartphones. The system consists of a web system and an android based mobile application. The web system and the mobile application communicate with each other using an encrypted data structure that contains the sensor data and recognisable headings. The raw data, according to recognisable headings, is stored in the Amazon Relational Database Service which is backed up daily.

2. Significance of BP, SPO2, Heart rate, Body Temperature

The SpO2 stands for the peripheral capillary oxygen saturation. It is the estimation of the amount of oxygen present in the human blood. In other words, we can explain SpO2 as the ratio of hemoglobin that contains oxygen to the total concentration of hemoglobin that is present in the blood of a human being. SpO2 is the estimation of the oxygen saturation in the arteries, which represents the oxygenated hemoglobin in the human blood. Hemoglobin is a protein that is found the RBC's in the blood. It is responsible for carrying oxygen from lungs to the different parts of the body. The oxygen from the lungs is absorbed by the hemoglobin present in the blood and as the blood flows to the different parts of the body it supplies oxygen that is stored in the Hemoglobin.SpO2 is an estimate of arterial oxygen saturation, or SaO2, which refers to the amount of oxygenated hemoglobin in the blood.SpO2 can be measured by pulse oximetry, an indirect, non-invasive method (meaning it does not involve the introduction of instruments into the body).It works by emitting and then absorbing a light wave passing through blood vessels (or capillaries) in the fingertip.A variation of the light wave passing through the finger will give the value of the SpO2 measurement because the degree of oxygen saturation causes variationsin the blood's colour.

The normal human body temperature is 98.6 °F (37 °C). The temperature of the human body varies in different conditions like when a person is suffering from infection or based on the activities performed. The body temperature is one of the most important term in the medical field. The maintenance of body temperature at a constant state is very important as many metabolic activities and chemical reaction that happens in the body are temperature dependent and the slight change in the body temperature will affect these chemical reactions that are essential for the normal functioning of the body.

Blood Pressure(BP) is the pressure of the circulating blood on the walls of blood vessels. Blood Pressure is usually expressed in terms of systolic pressure over diastolic pressure. BP is important because, the higher the BP, higher the risk of health problems in life. If the BP is high, it is putting extra strain on the arteries and on heart. Over time, this strain can cause the arteries to become thicker and less flexible, or to become weaker. If arteries become thicker and less flexible, they will become narrower, which results in clogging up of arteries. This can lead to heart attack, stroke, kidney disease or dementia.

Heart rate is the speed of the heartbeat - measured by the number of contractions of the heart per minute (bpm). Normal heart rate varies from person to person. Conventionally heart-rate is measured on wrists, elbow, above the foot and beside the neck. As we age, the rate and regularity of the pulse can change and may signify the heart's condition. Heart rate of a resting person is between 60(bpm) and 100(bpm). Factors like air temperature, body position, body size and medication used also affect the heart rate. Beta blockers slow down the heart rate while the thyroid medications raise it.

3. Methodology

The Integrated health monitoring system designed and implemented in this project consists of three main modules i.e. BP module, SpO2 module and IR Thermometer. The Figure 1 shows the block diagram of the integrated health monitoring system.

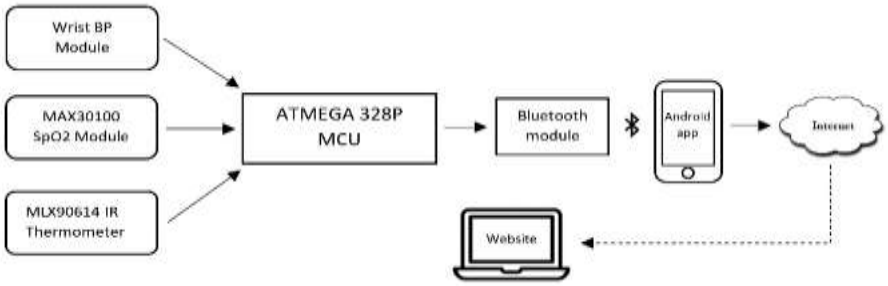

Figure 1. Block diagram of Integrated health monitoring system

Pulse oximeter sensor MAX30100 uses a transmitter with red and infrared LEDs that shines through a reasonably translucent site with a blood flow. The receiver consists of a photo-diode. The basic principle behind this type of pulse oximetry is the fact that absorption due to tissue, skin or muscle remains constant, whereas absorption due to arterial blood varies.

The absorption of light by the blood-stream is affected by the concentration of HbO2 and Hb. The absorption coefficients are measured using two wavelengths 660nm (red light) and 940nm (IR light). The acquired data is communicated to the MCU by I2C protocol. The functional block diagram of the pulse oximeter used is given Figure 2.

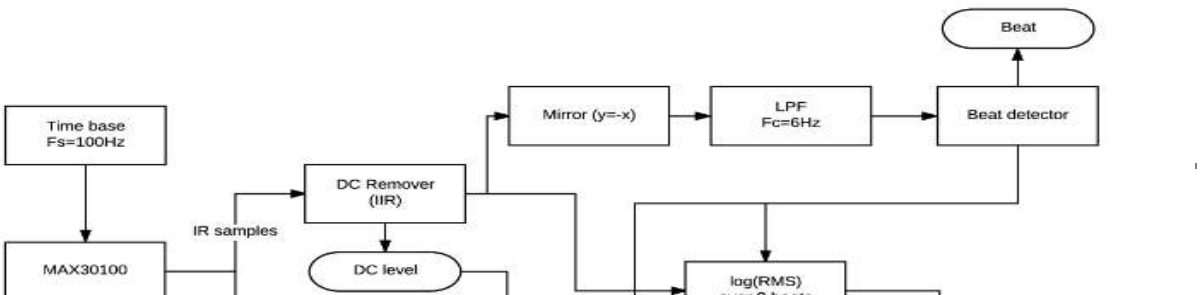

Figure 2. Block diagram of SpO2 monitoring system using MAX30100

The IR Temperature sensor used - MLX90614 is a highly accurate temperature sensor which is optionally available for medical purposes with high accuracy in the body temperature range and has an internal 17-bit ADC to convert IR temperature sensor reading to a digital value. The data is communicated to the MCU by I2C protocol.

The BP module is an external module (from sunroom) which has to be connected to the IHMS module by the DB-9 connector. The BP module is a sub-system which consists of a microcontroller, inflator pump, valve, etc.

The cloud service used in this system is ThingSpeak – a free IoT platform by Mathworks. It allows monitoring of upto 8 fields. Various IoT platforms are available for free like thingspeak, xively, ubidots, IBM bluemix which offer free services for limited time. They provide good data security as the channels made here are unique, customizable and privacy can be set to public or private depending on the interest of the user. The fields used in this project are Name, Aadhar UID, Phone number, Body temperature, SpO2, Systolic BP, Diastolic BP and Heart rate. The data is displayed on the website: http://ihms.web44.net/ which can be accessed by qualified doctors who can provide diagnosis information remotely without being in the hospital. This is a major advantage in case of health monitoring in rural areas where sophisticated healthcare facilities are not available. The QR code to the IHMS website is shown Figure 3.

Figure 3. QR code of the website: http://ihms.web44.net/

4. Results

The Systolic & Diastolic pressures and the Heart rate are computed by the on-board microcontroller and is communicated with the main MCU by serial communication protocol. The main MCU – ATMEGA328P controls all the operations – Data acquisition from the sensors, organising the acquired data and Wirelessly communicating the information to the smartphone via Bluetooth serial communication.

The health parameters from the IHMS module are acquired by an Android app. The data is then displayed in a user-friendly GUI. The personal details of the person are given by scanning the QR code

from Aadhar card. The data can also be entered manually. The data packet, comprising the personal details and the vital health parameters, can be locally saved on the device. This data packet can be uploaded to the cloud when the phone is connected to the internet.The complete hardware was designed and built and enclosed in a robust enclosure as shown in Figure 4. The different sensors are integrated and the person can take the measurement as shownin Figure 5.

Figure 4 The Integrated Health Monitoring Module

Figure 5 SpO2 measurement

The SpO2 module used is MAX30100 by Protocentral. The specified tolerance of the Saturated oxygen content is around 2-3 %. This pulse oximeter is based on reflected light which is very different from the conventional transmission type. Hence the error of measured saturated oxygen level can go upto 4% under certain circumstances. If medical grade sensors are used, then even these errors can be completely avoided.

Since we are mainly concentrating on storing the data in a database, we are not using the medical grade sensors. This module is superior when compared to other health monitoring devices in its ability to store the measured data in the cloud and easy access by patients and doctor from anywhere and anytime.

The BP module used in this work is a wrist BP module as shown in Figure 6, which computes the value and directly transmits it to the MCU serially. The conventional ones used in hospitals are worn around the upper arm whereas the one used here is worn around the wrist. Usually the measurement carried out in the wrist has the tendency to be higher has the one measured around the upper arm. Systolic BP values have an error of up to 10 mm of Hg and Heart rate measurements of up to 5 bpm.

Figure 6 BP through external module

Figure 7 Micro USB power jack and BP module connector

The power supply of the IHMS module is uniquely designed in such a way that it can be powered using its internal battery as well as external USB power. Figure 7 shows the Micro-USB port and the DB-9 connector to connect BP module.

The module runs on battery for upto 8 hours without BP module and upto 20 minutes when used with BP. The Micro-USB jack allows the user to directly run the module from a power outlet or a power bank
The Software part consists of the Android app and the Cloud. The Android app is a custom-made one to work exclusively with the IHMS module. The app is user friendly and takes up minimal space. The screenshots of the apps are showm in Figure 8.

Figure 8 Screenshots of the IHMS Android App

The cloud part consists of ThingSpeak IoT platform. HTML code was developed to retrieve the records from ThingSpeak and it was hosted by a free service on the required domain - http://ihms.web44.net/. The screenshot of the website is shown in Figure 9. The data can also be obtained in graphical form from the ThingSpeak website. The data can be accessed by sophisticated doctors and give their diagnosis data to the person using his/her mobile number. The data can also be exported in a pdf or MS Excel format for easy and improved analysis.

Figure 9 Screenshot of the IHMS website

5. Conclusion

The main objective of this project was to provide basic yet vital health monitoring platform, which is at par with the current IoT technology, to rural India to improve their Healthcare infrastructure. This objective was comprehensively achieved by designing, building and validating the complete IoT based Integrated Health Monitoring System. The main feature of this project was the cost effectiveness and ease of maintenance of a database for the patients. Due to the compactness of the module it is easily portable. The

system has been field tested. The accuracy and reliability of the sensors were verified during the test. The system is able to monitor the health condition for 24 hours a day and 7 days a week due to its unique power supply design which enables it to run on battery as well as USB power. The app is user friendly and allows the patient himself to upload the data to the database after recording the necessary parameters without the need of a second person. The app allows the user to scan the QR code of the Aadhar Card. This way, the complete medical history of the patient is synched with the user's Aadhar UID. This project would be of great use to the patients from rural areas, who otherwise have to travel longer distances to consult a doctor.

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