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A Smart IoT Architecture for Continuous Health Monitoring Using Raspberry Pi for Pandemic and Emergency Conditions

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Abstract

The increasing demand for noncontact and continuous health monitoring during pandemic and emergency conditions has significantly accelerated the adoption of Internet of Things (IoT) technologies in healthcare. IoT health monitoring systems obviate the need for frequent doctor visits and patient-physician consultations. This paper presents an IoT-based real-time patient health supervision system using Raspberry Pi for track a person's temperature, pulse rate, humidity, and oxygen saturation. This approach is particularly beneficial in rural or village areas, where local clinics can share their patients' medical information with larger city hospitals for better diagnosis and treatment. The proposed system integrates temperature, pulse rate, and humidity sensors to observe the patient's health status with high accuracy. The suggested system consists of three parts: an inexpensive, lightweight IoT sensor, a mobile cloud server called Thing Speak, and a qr code scanning technique for data processing and diagnostics. ThingSpeak updates the data, and then the patient's health status is displayed. Although motivated by COVID-19 needs, the system is designed as a general-purpose tele-health solution suitable for elderly care, chronic disease monitoring, home quarantine, remote hospitals, and future pandemic preparedness. Experimental results demonstrate that the system is cost-effective, scalable, and reliable for modern healthcare environments.

Keywords Smart Health Monitoring: Pandemic preparedness: IOT: Thingspeak: Raspberry Pi.

Introduction

The Internet of Things (IoT) is an advanced technology that integrates seamlessly with various aspects of human life. In the healthcare sector, IoT has brought significant transformation by enabling automated systems that support real-time remote monitoring and continuous observation of patient health (Valsalan et al., 2020). The worldwide healthcare systems encountered three major challenges during COVID-19 because they lacked enough medical personnel while dealing with excessive patient numbers and rising dangers of viral spread through direct contact (Lim and Dhakshyani, 2024). The healthcare industry needed to create smart monitoring systems which operated without human contact to provide continuous monitoring while minimizing manual involvement (Bhardwaj et al., 2022).

Several studies have explored IoT-based health monitoring using wearable sensors, mobile applications, and cloud-integrated systems. Although these methods provide remote accessibility, many existing solutions face limitations such as high cost, lack of real-time data transmission, restricted scalability, and insufficient reliability during emergency conditions. Additionally, many previously developed systems depend on bulky hardware or architectures, making them unsuitable for resource-constrained or rapidly changing healthcare environments (Abdulmalek et al., 2022).

In spite of the significant advancements in medical technology, there is a constant gap in terms of design for an affordable, portable, and real-time health monitoring system that can run in a pandemic, natural disaster, or emergency medical situation. An effective solution needs to provide 24/7 monitoring of vital signs, immediate alerts, and require little human interaction. Accordingly, there is a strong need for a compact and efficient Internet-of-Things (IoT) based system to remotely monitor patient health using easily deployable hardware platforms, such as the Raspberry Pi. Accurate and continuous monitoring of patient health is essential for improving clinical decision-making and ensuring timely medical intervention. This section reviews recent advancements and the latest developments in IoT-based health monitoring systems, highlighting how sensor technologies, cloud platforms, and embedded devices such as Raspberry Pi are being utilized to enhance remote healthcare services. Kodali et al. (2016) presented the use of healthcare system to find the patient's temperature. IoT-enabled devices simultaneously improve care quality through active data collecting and monitoring on a regular basis, while lowering costs for care and its analysis.

Catarinucci et al. (2015) proposed an IoT-based system for the monitoring of patients, self-health check reporting and management of biomedical equipment in nursing schools and hospitals. Kulkarni and Sathe (2014) also explored the role of IoT in providing personalized healthcare without compromising on quality or costs. They elucidated both the operation of IoT systems as well as how wireless communication and remote sensing technologies can be utilized to provide solutions for different healthcare endpoints. Mazumder (2021) used an IoT-based approach, to monitor blood pressure, body temperature, heart rate and levels of oxygen. There are various products on the market that may be used to find important indicators like body temperature, pulse, and ECG. Kamarozaman and Awang (2021) developed an IoT to measure portable Covid-19 health monitoring system. In this study, the data was focused on using Node-Red and the ThingSpeak approach, with the MQTT protocol sending the data to Node-Red and the cloud. The Raspberry Pi is the primary Internet of Things board, and it gathers data from sensors. Taiwo and Ezugwu (2021) applied intelligent healthcare solutions for telemonitoring patients at home over the COVID-19 lockdown. The research demonstrated a mobile application prototype, which aims to support elder and disabled people for their independent and comfortable life at home. Petrovic and Kocic (2020) explored a monitoring system for an indoor IoT-based monitoring system using an Arduino setup to perform the contactless monitoring of the body temperature, compliance of the mask, and social distancing. Bhoomika and Muralidhara (2015) introduced an IoT-based smart healthcare system designed to continuously track patients' vital parameters. Through IP addressing and reliable data storage methods, healthcare providers can remotely access the collected readings using an HTML-based web interface, enabling effective monitoring and timely analysis.

This study aims to develop an IoT-based real-time patient an intelligent health observation system built on Raspberry Pi to support remote observation and timely healthcare response during pandemic and emergency conditions (Gutte and Vadali, 2018). In this system, key health sensors used to measure pulse rate, body temperature, and environmental humidity are linked to a cloud platform for uninterrupted collection, processing, and sharing of data. The Raspberry Pi serves as the primary controller, performing rapid analysis of the incoming readings and automatically issuing alerts whenever any parameter deviates from the normal range. The overall objective of the proposed research work is the development and evaluation of a scalable IoT architecture to be used in remote patient monitoring. In this present work, a low-cost IoT architecture was created based on Raspberry Pi and open-source technologies, which allows to roll out on a large scale at hospitals, quarantine centers, in rural health camps, and home-isolation settings.

Materials and Methods

The overall architecture of the proposed IoT-based real-time patient health surveillance system is depicted in Fig.1.

System Design

In this work, we will discuss effective, necessary, and convenient sensors. We are discussing three basic sensors, which are applied to monitor three vital signs (measured in the hospital capacity): body temperature, humidity, and pulse. The health reading of the patient is measured continuously in this system using a range of biomedical sensors like the DHT11 to measure temperature, ECG module measuring heart activity and pulse sensor to measure the heart rate. The acquired data measurement is transmitted in real-time and sent to the Raspberry Pi, which is used as the central processing unit of the data obtained.

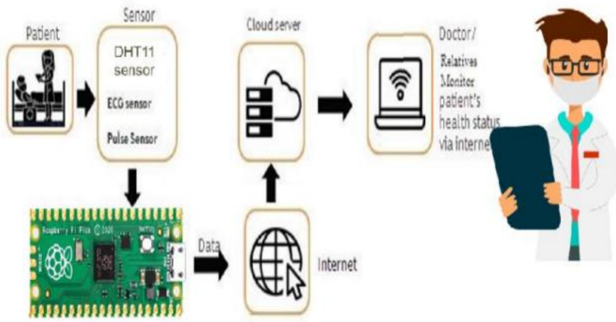

Fig. 1 Flow of the proposed architecture

The Raspberry Pi receives the sensor data and undertakes initial pre-processing and prepares the information to be transmitted. The resulting data is then transmitted to the server of the cloud via an internet connection, which allows secure storage and easy accessibility. After being uploaded into the cloud, the health parameters of the patient can be accessed and examined by a doctor or a family member using a web-enabled dashboard. This enables authorized users to always keep track of the health status of the patient wherever they go and take immediate action in case of abnormal readings or emergencies.

Software Architecture

The software execution, which acts as the brain of the patient health supervision system while keeping user flexibility, is one of the project's most crucial components. The microcontroller, which is where we store the data and retrieve it based on the sensor value, is the crucial infrastructure. Raspberry Pi gathers information and transmits it to the ThingSpeak web application. For storing real-time data, cloud storage is a particularly effective server location. By entering the correct user ID, password, and write API key, the system receives the data and displays it across different fields within the designated channel. Patient information is safe in this database because it is password-protected, allowing only authorised people to access it. The first and most crucial step in creating any form of software project successfully is requirement analysis.

ThingSpeak

ThingSpeak is a free online IoT platform that is developed on top of Ruby and enables communication with devices connected to the internet as illustrated in Fig.2. It simplifies the data acquisition, retrieval and logging processes by offering an API that is available to hardware and web based applications. The platform is a product of the IoBridge and was launched in 2010 to assist IoT developers to build connected and data-driven systems. Being a cloud-based solution, ThingSpeak provides a set of in-built IoT analytics features, allowing one to retrieve, store, and visualize real-time data streams in an efficient manner. Data visualisation and analysis are also made available. Some important concepts of ThingSpeak: You may post information on your device to ThingSpeak. Concurrently you can create a flow of real-time data to do visualisation and alert when required. ThingSpeak is a cloud based platform that gathers data streams, visualises and analyses real time data streams. ThingSpeaktm is an IoT analytics service which helps the real-time data streams of the internet to be acquired, visualised, and interpreted. The information is instantly rendered in its channel when a device sends data to the platform.

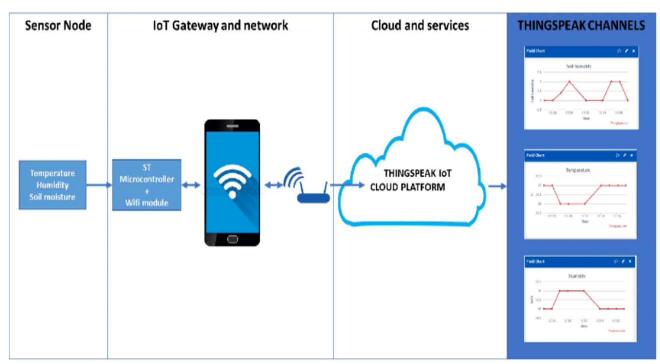

Fig.2 ThingSpeak platform

Hardware Components

The components of every IoT system are sensors and other kinds of devices. Hardware is anything that communicates with the actual thing. The precision of the analysis of the application's etiquette and the actual integration with the global system architecture are the two most important crucial components for this "thing" element. The setting of the device is another crucial element. Two types of configurations exist. The first involves internal configuration, and the second involves programming-based outward reconfiguration.

Raspberry Pi

The Raspberry Pi is the main processing board of the whole health monitoring system in this work. It incorporates different biomedical sensors by its GPIO, I2C, and SPI interfaces and real-time data acquisition and preprocessing. The Raspberry Pi has an integrated Wi-Fi and Bluetooth, which allows the device to be easily linked to the cloud to transmit data remotely. The existence of an operating environment that is Linux-based also facilitates advanced computations and secure data handling (Aziz et al., 2016). Due to its low prices, small dimensions, and processing power, the Raspberry Pi gives the efficient and reliable system to monitor patient health at all times.

DHT 11

The DHT11 is a low-cost digital sensor designed to measure temperature and humidity. It uses an internal thermistor to detect temperature and a capacitive element to sense humidity, and then provides the combined readings as a digital output representing the surrounding environmental conditions. Although it can be utilised in a relatively straightforward manner, timing is crucial when dragging the data (Shankar et al., 2022). The sensor's only drawback is that you can only get new data from it once every two seconds. The sensor reading stays the same for 2 seconds after we implement the code because of this. Humidity sensors work by detecting changes in air moisture and reporting the corresponding relative humidity value.

Pulse Sensor

A pulse sensor is a device that is used to measure the heart rate of an individual in real time. It operates based on the fact that it detects the changes in the blood volume that take place each time the heart pumps blood (Mood et al.,2024). The photodetector detects the variation in the intensity of the light by the sensor when the sensor is placed on the tip of the fingertip and the light generated by its LEDs passes through the skin. This is then translated into pulse data that is readable. The pulse sensor is attached to the Raspberry Pi in a health monitoring system built based on Raspberry Pi by using the GPIO pins. The microcontroller picks up the analog pulse wave, works on it, and calculates the number of beats per minute (BPM). This will enable the system to constantly check the heart rate of the patient and show it in a dashboard or transfer the information in cloud services, like ThingSpeak, to be monitored remotely.

ESP8266 Wi-Fi Module

The ESP8266 is an independent Wi-Fi chip that comes with its own TCP/IP networking stack, enabling microcontrollers to establish wireless connectivity without needing external network hardware. It can either run its own application or provide wireless connectivity for an external application processor. In this system, the Raspberry Pi interfaces with the ESP8266, which collects all sensor readings and transmits them to a ThingSpeak channel. The NodeMCU variant of the ESP8266 also contains an asynchronous serial communication interface, enabling smooth data exchange with the Bluetooth module (Mitra et al. 2023).

Results and Discussion

After a brief interval, the module turns on to calculate the vital statistics of pulse rate, humidity, and body temperature. We guarantee that every linked sensor is regularly checked, but because some of them are a little sensitive, it can be challenging to obtain the standard actual value. The data retrieved from each sensor is stored on cloud storage, which is then handled by ThinkSpeak server on the cloud. The temperature is uploaded to the cloud every three seconds, and the pulse rate is displayed fifteen seconds after an update. Depending on the user, every sensor value will be sent to the ThingSpeak cloud. When ThingSpeak receives the collection of sensor data from linked devices, the sensor data can be more easily visualised. On the ThingSpeak channel, the information is displayed graphically. The node MCU is a development board and open-source firmware based on Lua. It's an essential component of our system and was developed specifically for loT-based applications. The Node MCU transmits the measured value to the stationary server. The analysis of the parameters recorded is also detailed in the following subsections which include pulse signal analysis, body temperature analysis, performance in real life application and the identification results using the QR code.

Pulse Signal Analysis

On the first surface of this sensor, a light-emitting diode and an ambient light sensor are linked. The second surface is also connected to the circuit responsible for noise cancellation and amplification. The LED must be positioned directly on top of a layer before being placed above a vein in the human body, such as the tip of an ear or a fingernail. The LED starts to emit light as soon as it is placed on the vein. The patient's whole information was displayed on the pulse signal, which was then graphed in thingspeak. The patient's pulse measurements are shown in the Table 1.

Table 1 Patient Pulse Record

S.No.	Created_at	Entry_id	Field1
1	2022-04-20	251	93
2	2022-04-20	252	74
3	2022-04-20	253	82
4	2022-04-20	524	65
5	2022-04-20	255	78

Body Temperature Analysis

The body temperature of a person is among the most crucial indicators of their health. The boy's heart rate and blood circulation are both affected by variations in body temperature. In order to lower the body's temperature when it rises, the blood circulates more swiftly throughout the body. The graph below illustrates how the patient’s body temperature varied over the course of the monitoring period. the depiction of a rise in body temperature that occurs when a patient is physically stressed, as well as the ambient temperature. The patient stopped moving and sat down to rest, allowing his body temperature to gradually return to normal. Table 2 summarizes the detailed observations of the body temperature. The measured results indicate that the temperature sensor was accurate and its values did not vary significantly in the successive measurements. These findings confirm the ability of the system to monitor temperature changes continuously and send the information to the cloud in real-time.

Table 2 Patient Temperature Record

S.No.	Created at	Entry_id	Field3
1	2022-04-20	251	37
2	2022-04-20	252	32
3	2022-04-20	253	36
4	2022-04-20	254	29
5	2022-04-20	255	38

Real Life Usage

After connecting every sensor to a patient, we run the module. Before taking the readings of heart rate, body temperature, and humidity, we made sure that all of the sensors were firmly in place. It was occasionally difficult to obtain an accurate standard value since the sensors were so sensitive. The retrieved sensor values were then saved in Bea storage, where the ThingSpeak cloud server later accessed them. We gathered the data under two separate conditions to facilitate analysis. The graph below depicts the variations in the patient’s health parameters recorded both during rest and after physical activity. The patient's pulse rate appeared to be normal, and he was resting down in a field. The average resting pulse rate was 65-75 bpm. The patient's body temperature pattern at rest and following activity is shown in Fig.3 a, b, c.

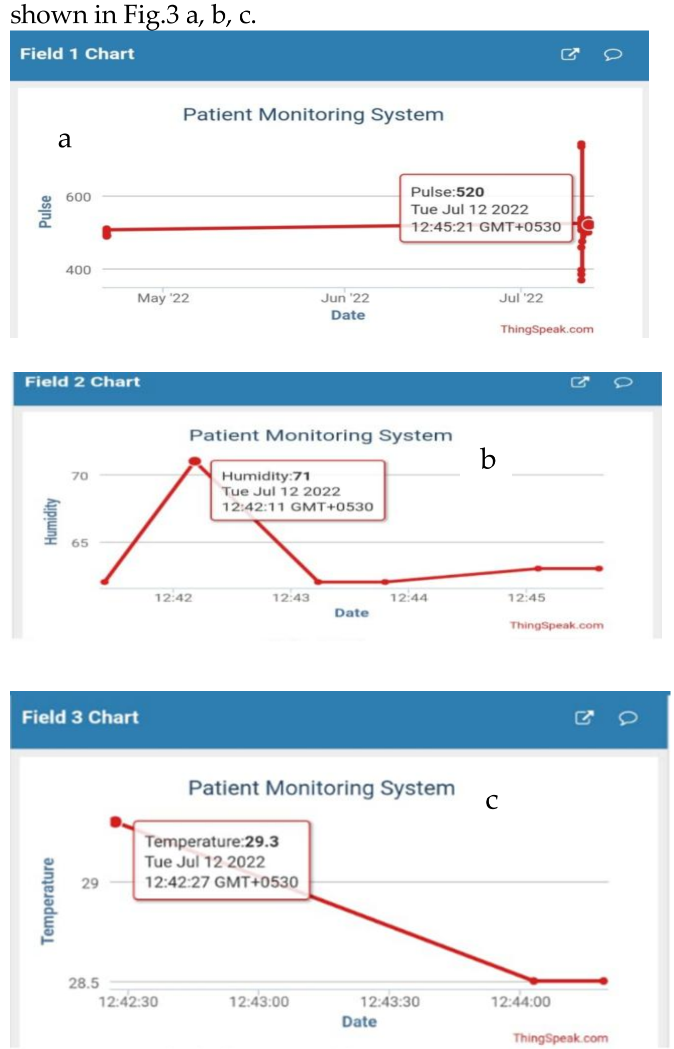

Fig. 3 (a) Pulse rate data in ThingSpeak, (b) Humidity data in ThingSpeak, (c) Body temperature data in ThingSpeak

Field 1 contains data on pulse, Field 2 has information on humidity, and Field 3 contains information on body temperature. These data were all extracted using QR code from Thingspeak. All of the data in this project is fetched via a QR code, making it incredibly user-friendly for anyone who wants to display patient data.

Table 3 Patient Physiological Parameters: Pulse, Temperature, and Humidity

S. No.	Created at	Entry_id	Field 1	Field 2	Field 3
1	2022-04-20	251	93	40	37
2	2022-04-20	251	74	36	32
3	2022-04-20	253	82	38	36
4	2022-04-20	524	65	30	29
5	2022-04-20	255	78	54	38

QR Code Analysis

This code is crucial to the project since it retrieves all sensor data using QR codes. This QR Code activated the ThingSpeak Link and downloaded all available data from the cloud. All data was loaded into the cloud using a raspberry pi and a node MCU. The QR code is show in Fig. 4.

Fig.4 QR code

Conclusions

The suggested real-time patient health surveillance system is an IoT-based solution with an efficient, cost-effective, and scalable solution to continually monitor vital physiological measures of patients in the home and in clinics. The combination of temperature, ECG, and pulse rate sensors with the Raspberry Pi platform provides the system with the reliability of data capture, edge-level processing, and unrestricted connectivity to the cloud. The created framework enables medical workers and caregivers to view patient information remotely, monitor their long-term health patterns, and get real-time notifications in case of emergency situations. This contactless and automated monitoring method is an excellent way to limit the number of physical check-ups done on a regular basis and especially under the circumstances of the pandemic or outbreak of contagious diseases, as well as increase response time and patient safety overall. The findings indicate that the developed architecture is strong, simplifies the implementation process and is applicable to real-time healthcare applications.

Despite the effectiveness of the system, some improvements can be made to enhance the accuracy, adaptability, and clinical usefulness of the same. To begin with, other biomedical sensors like blood pressure, respiratory rate and blood glucose sensor can be added and thus form a more detailed monitoring platform. Any machine learning method can be used to identify anomalies, predict diseases, and recommend personalized health information based on the long-term data trends.

Data Availability Statement

The datasets generated during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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