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Real-Time Health Monitoring System using IoT for Comatose Patients

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Abstract: Internet of Things (IoT) based smart devices has been reshaping human life through assisting in making smarter decisions and yielding response to the users based on analysis of data. Among various aspects of life, patients require continuous care and uninterrupted monitoring. IoT makes this possible by providing real-time monitoring of various health conditions of patients. Specifically, IoT based health monitoring systems act as an effective solution for the patients and doctors. In this paper, a soft real-time health monitoring system based on an android application and a web-based monitoring portal is developed for comatose patients. Using the developed system a doctor can monitor conditions of the patients. The system is developed using a Raspberry pi microcomputer and the health related sensors. The system collects the information like heartbeat rate, blood pressure, urine level, temperature, humidity, and motion detection using the sensors. It alerts doctor if any parameter exceeds the normal limit. Moreover, it also updates status on the database and the developed application. The proposed system can effectively able to monitor the health condition of a comatose patient in real-time using IoT.

Keywords: Real-time; Mobile Application, Firebase, Health Monitoring; IoT

I. INTRODUCTION

Internet of things (IoT) involves various sensors and processing units for data collection and transmission from multiple sources such as manufacturing units, healthcare systems, domestic application systems, automobiles, etc. IoT allows to monitor using various wireless sensing nodes and allows to interact with one another through a communication network. This is an interconnection of the various services and devices which are minimizing human efforts and making human lives easier. Basic IoT architecture involves sensors, processing units, and network communications which allow to share data between various devices. This is also extending the abilities to capture, transmitting, and processing data through various real-world devices, which enable effective monitoring, controlling, and automating various processes [1]. IoT has been playing major role in evolution of wireless communicating technologies by enabling communication capability in cameras, thermostats, and wearable sensing devices. IoT in healthcare is better named as the internet of medical things (IoMT) which involves a variety of sensors which are essentially required to monitor health conditions of patients in hospitals or homes. It also provides real-time localization with health monitoring capabilities [2]. Researchers have developed various health monitoring devices to examine undesirable and uncontrollable transformations which occur in body-parameters of a patient. These devices can automatically send alerts to the doctor and/or practitioner. A doctor may evaluate patients anywhere in the globe with the help of different IoT devices [3, 4].

Various wireless sensing networks are allowing healthcare monitoring and assisting doctors to effectively monitor their patients [5]. Hence, IoT based devices are getting popular day by day, and numerous health problems which need early diagnoses can be effectively diagnosed [6]. The researchers also have been developing various IoT based wearable devices and web-based patient health monitory systems for remote patients' diagnoses.

The Fig. 1 showing that communications between IoT platform, networking devices, and sensors. Doctors, patients, and other concerned people can be interconnected with one another through a communication network. Patient's record and health related updates may easily be saved in database. Moreover, concerned persons may access information whenever they require it. IoT is acting as revolutionary shifts in the fields of internet based communications and this is contributing greatly to growth of the field [7]. Researchers have been developing low-cost systems to improve human health and providing e-health services [8, 9]. In the last couple of years, this field has drawn huge attention of the researchers for addressing various problems of IoT in health care by considering various challenges. Amongst various research considerations some include network architectures, communication technologies, user interface, functionalities, and security systems. [10, 11]. In this direction, the authors of [12] have developed a new wireless system for remote monitoring of the heartbeat rate and oxygen saturation. A pulse oximeter is used to measure the oxygen level in the blood and the heartbeat rate of the patient. The data is acquired and then transferred through a wireless sensor network (WSN)

to a central monitoring station. An alarm is triggered automatically if any issue arises. To show the results of the patients, a graphical user interface (GUI) is also developed.

A healthcare system based on IoT was proposed by the authors of [13]. The system is considered to be a safe in terms of information security. Two communication mechanisms have been created with the use of robust one for protection between nodes and another for ensuring confidential transmission. The healthcare system is integrated to the Raspberry pi microcomputer to demonstrate the usefulness and effectiveness of the mechanisms. In [14] authors have developed a smart Intensive Care Unit (ICU), using a framework that is developed to track patients those are at risk. In order to take precautionary measures, the device informs and warns the doctors/medical assistants in real-time about the patient movement and about major changes in the environmental specifications.
In [15], researchers have conducted a qualitative research method, focusing primarily on resources to acquire important information related to security issues in healthcare domain. The researcher created a conceptual framework and an algorithm to address security issues that arise when a doctor and patient share information. The proposed framework allows to establish a reliable health diagnosis system.

The authors of [16] have developed a health monitoring android application and have used a pulse sensor to detect heartbeat rate of the patient using Arduino UNO. The developed system allows communication between doctor and patients through SMS alerts including pulse rate and location information of patient. The purpose of developing the application was to save lives of patients in the worst health conditions. In [17] authors have developed a real-time health monitoring system using GSM and four health related sensorss such as temperature, heartbeat rate, accelerometer, and eye blinks. The sensors were integrated with a GSM module for online monitoring. The purpose of making the health monitoring system was to observe the parameters in real-time and give message alerts to the doctor/relatives in short time via mobile in case of emergency. The system depicted slow response during eye blinking detection due to large image processing time. The authors of [18] have developed a user-friendly android application that collects pulse rate of the patient. The data is transferred to a cloud using ESP2566 board and then the data is transferred and displayed on the application. Both the physician and patients can view the health related information. It allows patients to monitor their health status themselves without consulting a doctor. The developed system was only able to monitor the pulse rate.

Compared to the aforementioned work, in this research we have proposed an IoT based health monitoring system for comatose patients. The system is developed using components which consist of a Raspberry Pi microcomputer, IoT platform, eye blink sensor, temperature sensor, humidity sensor, heartbeat sensor, urine level sensor, motion detection sensor, pump for feeding, and Electromyography (EMG) sensor. Coma is a critical state in which patient needs continuous monitoring of different parameters. The Raspberry-Pi based health monitoring system allows efficient remote monitoring of the patients through a mobile application and the Firebase platform. In this project, the Raspberry Pi microcomputer acts as data acquisition and processing unit with the capability of wireless data transmission to the IoT platforms. The proposed system will ensure the comatose patient's safety and will alert at the right time before some unwanted event occurs.

The remainder of this paper is organized as follows, Section II reports the components used to develop the comatose health monitoring system, Section III discusses the method employed for the implementation of the system, and Section VI presents and discusses the results. Finally, conclusions are provided in Section V of the paper.

II. System Components

This section presents components used for the development of the comatose health monitoring system. Each component is discussed as under:

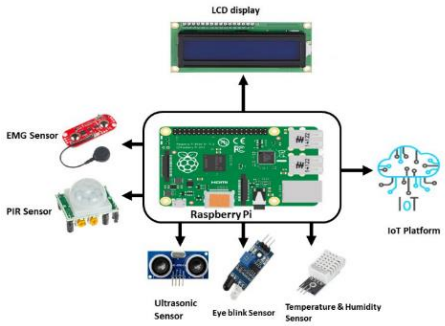

Figure 1. An IoT based healthcare system

A. *Raspberry Pi Microcomputer*

The Raspberry-Pi model 3B+ is used for the development of the health monitoring system. It has been in the attention of hobbyists and engineers due to its inexpensiveness, easy interfacing, and easy programming with python. It is a Linux operating system (OS) based microcomputer with Wi-Fi and Bluetooth facilities. The pocket-size microcomputer board can perform various tasks in real-time just like a general-purpose computer [19]. Considering its advantages such as on-board wireless connectivity and efficient data processing this board has been used in this project.

B. *PIR Sensor*

The HC-SR501 PIR is an infrared technology-based sensor. Its range can be adjusted through a potentiometer. It can detect objects between 3 to 7 meters. The purpose of using the PIR sensor is to detect the body motion of comatose patients if any kind of motion occurs then that could be monitored.

C. *Ultrasonic Sensor*

The HC - SR04 ultrasonic sensor is used for detecting the urine level in the bag. It allows non-contact measurement between

the ranges of 20 to 400cm. It works based on three sub-modules including a transmitter, receiver, and a control circuit.

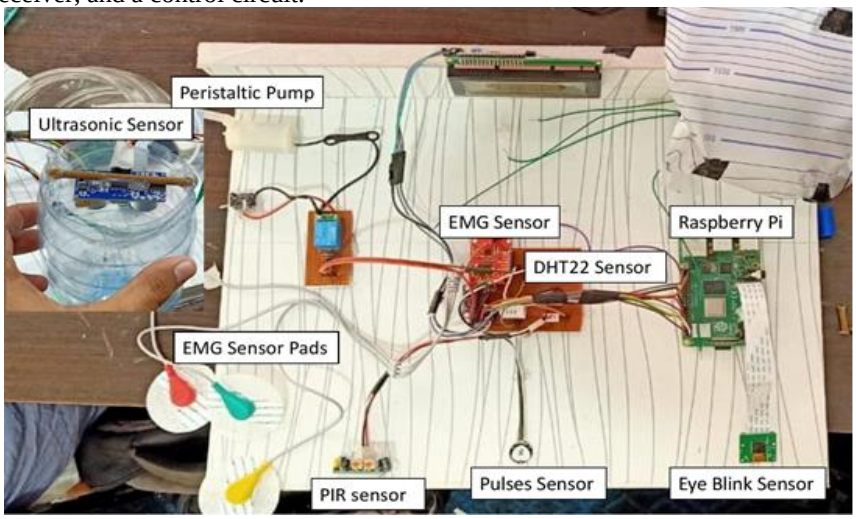

Figure 2. System Components

D. Pump

The peristaltic pump is used for feeding the comatose patients. One can receive alerts at the fixed time of feeding through the mobile application or the web-portal.

E. Eye Blink Sensor

The eye blinking sensor is used to detect the status of eyes of comatose patient on two conditions either patient's eyes are opened or closed with the help of a Pi-camera.

F. Temperature and Humidity Sensor

The DHT22 is a digital type sensor that is used for measuring the temperature and humidity of the ward. It uses single data bus communication with the microcomputer. It does not require any calibration and the output signals can be transmitted to a long distance.

G. EMG Sensor

The EMG sensor is employed to measure muscle activation through electric potential in order to diagnose neuromuscular disorder. For reliable use of this sensor, it should be placed properly on muscle. The position and orientation of the sensor greatly effects the output signals of the sensor. For correct placement, one electrode of the EMG sensor should be placed in the middle of muscle and other electrode should be placed in the direction of muscle length. Moreover, as per recommendation of the manufacturer the senor should be operated with the default gain for reliable functioning.

H. Pulse Sensor

This sensor is an optical type pulse rate sensor which used for measuring the pulse rate of coma patients. The alert notification is received through the firebase whenever the value goes below or above the safe limits.

TABLE I. SPECIFICATIONS OF THE SENSORS

S. No.	Sensors	Operating Voltage Range	Weight	Dimensions	Operating Temperature Range
1.	PIR Sensor [16]	4.V to 12V	5.87g	32mm x 24mm x 28mm	-20°C to +80°C
2.	Ultrasonic Sensor [17]	5V	8.5g	45mm x 20mm x 15mm	-
3.	Peristaltic Pump [18]	12 V DC	3.6 Kg	33 cm x 13 cm x 17 cm	0°C to - 40 °C
4.	DHT22 Sensor [19]	3.5V to 5.5V	2.4g	15.3mm x 7.8mm x 25.3mm	-40°C to 80 °C
5.	EMG Sensor [20]	2.9V to 5.7V	30gm	0.82inch x 2.06inch	-
6.	Pulse Sensor [21]	3.3 to 5V	10g	4mm x 0.5mm x 6mm	-40°C to +85 °C

III. SYSTEM IMPLEMENTATION

. The comatose health monitoring system is developed using an eye-blink sensor, temperature sensor, humidity sensor, heartbeat sensor, urine level sensor, motion detection sensor, pump, and EMG sensor. The eye-blink detection system uses a pi camera and an algorithm which captures and processes images and enables to detect the blinking of an eye of a comatose patient. In order to detect whether eye is blinking or not a camera is installed in front of patient in such a way that it can easily focus on patient's face. The Haar cascade algorithm is employed to detect the eye blinking of the patient. The DHT22 sensor is installed to measure the real-time room temperature and humidity. The heartbeat sensor is employed to measure the heartbeat rate of the patient.

Subsequently, a pump allows for feeding a coma patient. Push buttons are added in the mobile application to start and stop the feeding process as per the requirement of the patient. When push button is pressed feeding will automatically be initiated through Raspberry Pi with the help of the nasojejunal tube. The electromyogram (EMG) sensor monitors the electrical activity of muscles at rest and during contraction. The ultrasonic sensor continuously measures the urine level. The PIR sensor detects the motion of the patient. The heartbeat sensor monitors s the pulse rate of the patient. All the data is transmitted from the sensors to the Raspberry pi microcomputer. Where data is processed, stored, and the results are displayed on the LCD and transmitted to the IoT platform. The IoT platform keeps track of the coma patient in real-time with the help of the Google cloud (Firebase). The overall data is sent to the cloud where it is stored and analyzed. Then, generated the results send to the mobile application. If there is any abnormality in the patient's health parameters, the mobile app will generate an alert notification on the mobile screen to aware the doctor or medical staff about the emergency and rescue the comatose patient.

Figure 3. Block diagram of the Health monitoring of comatose patient

Fig. 4 shows the working diagram of the eye blink detection system which uses the pi-camera and detects the eye movement through an image processing algorithm.

Fig. 5 depicts the flow diagram of the program which is implemented to monitor various health parameters of comatose patients.

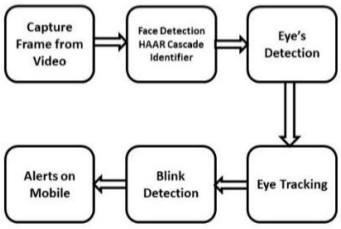

Figure 4. Eye Blink using Image Processing

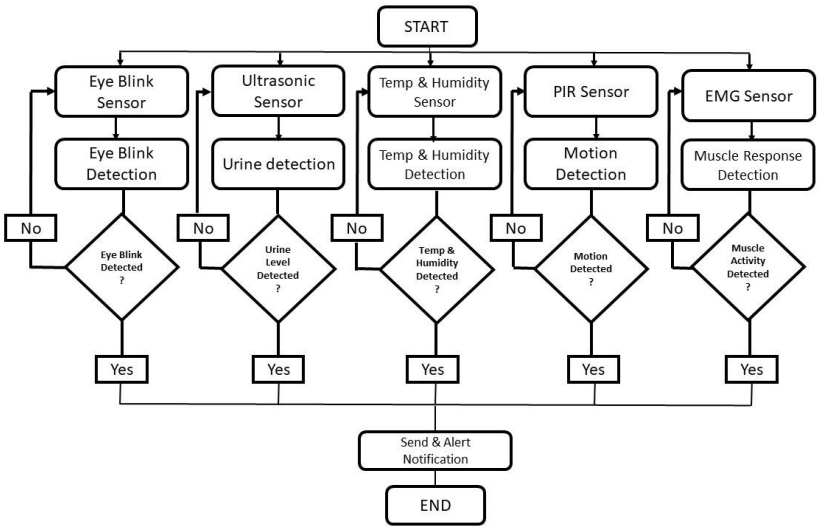

Figure 5. Flow Diagram of Health Care System for Comatose Patient

IV. Results and Discussions

This section reports and discusses the outcomes of the health monitoring system. The objective of this project was to monitor various health parameters of comatose patients. The developed system allows to continuously monitor various parameters of the patients through IoT. The sensed parameters such as eye blinking, pulse rate, temperature, humidity, and feeding status allowed to effectively monitor the comatose patient and allowed to avoid any danger to the patient.

Fig. 6(a) depicts the application that is used to show the motion status of the patient from the Firebase platform, it gives alerts on the application to assure the effectiveness of the system which can help to avoid harm to the patient. Fig. 6(b) shows the status of the urine level in the bag. It is tested by adding water in the bowl when it is filled, and the values are displayed on the mobile application and a corresponding alert message is generated. Fig. 6(c) shows the feeding status of the patient. Medical assistants can set the timing for feeding the patient according to the prescribed timings by a doctor. In Fig. 6(d) eye blink sensor is used to detect the status of an eye either open or closed. The sensor is attached to the wall or roof of the ICU in front of the coma patient. When a patient tries to open eyes, the system will detect the blinking of eyes and show the results on the app and notifies a doctor by producing sounds and store the results as the history of a patient. Fig. 6(e) and (f) show the results of the DHT22 sensor including humidity and temperature of the ward.

The DHT22 sensor measures temperature and moisture of the room, as humidity goes above the defined thresholds having a range of 30% to 60%, it generates the alert. This change will be shown on the application, doctor gets a notification for visiting the coma patient immediately. Fig. 6(g) shows the pulse rate of the patient. The EMG sensor measures the pulses generated by muscles which have the link to the pulses generated by heart of the coma patient. The sensor measures small electrical signals generated by patient muscles. Fig. 6(h) shows the results of heart rate of the patient, this sensor yields the heartbeat rate with the changes in blood level with respect to time. Lastly, we have got the overall results of the patients in the Firebase which are depicted in Fig. 7.

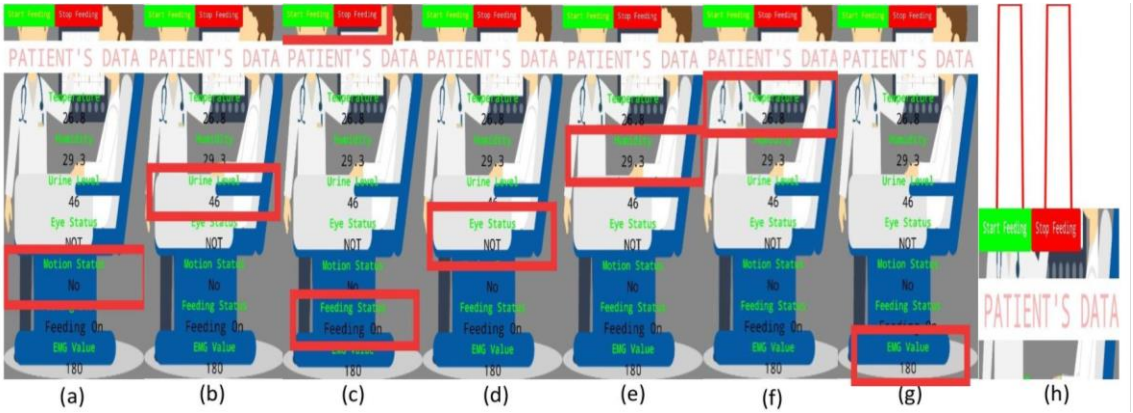

Figure 6. Patient's health parameters on the Application

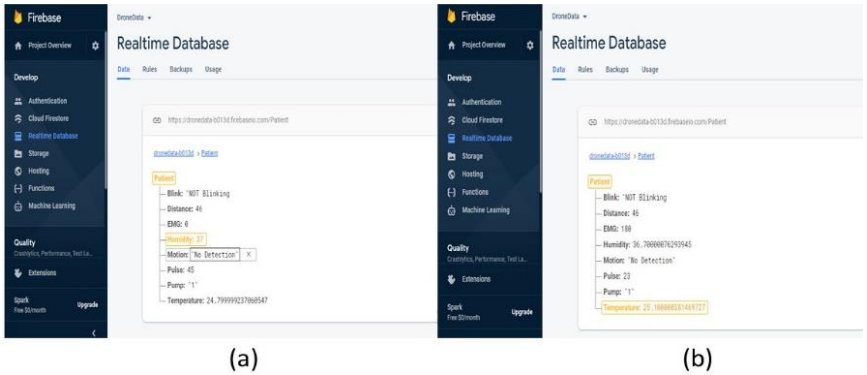

Figure 7. Patient's health parameters on the Firebase

The Firebase is used to show the data of the patients on the website, it also stores the results as a history of patients. Firebase shows the results in Fig. 7(a) for the DHT22 temperature of ICU. Fig. 7(b) depicts the results of the DHT22 humidity of ICU.

The developed comatose health monitoring system is able to continuously monitor various parameters of the patients. It is also able to generate corresponding alerts to the concerned persons if any anomaly occurs related to the health of the patients. Due to the use of wireless network, it allows real-time monitoring of the patients even in remote areas through the mobile application and the Firebase as IoT platforms. The system is developed using various cost-effective components such as Raspberry Pi microcomputer and other sensors. Compared to the study presented [17], in which researchers faced problem of the slow image processing, this system effectively detected eye blinking owing to the effective performance of the Raspberry Pi microcomputer.

V. CONCLUSION

In this research, an IoT based health monitoring system is implemented for the comatose patients. The proposed system has been developed using the Raspberry Pi, Firebase, and a mobile application. The main functions of this system are to check health parameters and store the patient's data in the Firebase, and provide alerts on the mobile application, simultaneously. Doctors and family members of a comatose patients can easily access the stored data using the application and the IoT platform. We have used Raspberry pi microcomputer, which offers more facilities such as easy connections with sensors and wireless internet. The device is used to track the comatose patient's health parameters. It collects the patient's data automatically using the sensors and the data is fed to the Raspberry Pi for processing. The microcomputer transfers the processed data through Wi-Fi to the Firebase cloud where data is stored and sent to the mobile application. In case of any emergency it generates an alert message on the application and web-portal. The developed health monitoring system will assist in avoiding harm to comatose patients through the use of modern technologies. In future work, the system can be upgraded through using machine learning for analysis of the data obtained from the developed health monitoring system.

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