An IoT based Remote Health Monitoring and Smart Assistance System with Sensor Technology for Paralyzed Patients

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***Abstract*— This research explores the integration of Internet of Things (IoT) technology into healthcare systems to assist paralysis patients. Paralysis, characterized by varying degrees of muscle function loss, presents challenges, particularly in mobility and communication. IoT offers solutions through remote health monitoring and gesture-based communication systems, enabling patients to communicate via minimal hand movements. The proposed system aims to address these challenges by incorporating biosensors to monitor vital signs and gesture-based controls for basic communication and home automation. Existing systems face limitations, including imprecise sensors and lack of mobile applications. This project seeks to overcome these barriers, providing a more accurate, efficient, and comprehensive solution to improve the quality of life for paralysis patients.**

Keywords—Internet of Things (IoT), Graphical User Interface (GUI), Paralysis, Wearable Device, Biosensors

I. INTRODUCTION

The impact of technology on healthcare has been profound, with the Internet of Things (IoT) emerging as a particularly influential innovation in recent years. IoT's applications span various aspects of life, but its potential in healthcare is especially significant. This ecosystem of internet-connected electronic devices facilitates long-distance wireless communication, enhancing existing healthcare systems by integrating medical resources to provide efficient, effective, and affordable care, particularly for patients with chronic conditions.

Paralysis, a neurological disorder characterized by the loss of voluntary muscle function, presents a spectrum of severity. It results from nerve damage and can manifest as complete paralysis, where patients have no control over affected muscles, or partial paralysis, where some muscle control remains. This condition significantly impacts patients' daily lives, with communication being a major challenge due to limited mobility and speech capabilities.

The rising prevalence of chronic conditions like paralysis has prompted engineers to develop innovative solutions using IoT technology. These systems aim to address basic yet crucial problems faced by patients. For instance, IoT-based monitoring systems can provide continuous oversight of patients' well-being. Additionally, for those with partial paralysis, IoT devices can detect minimal finger movements, enabling basic communication and potentially improving patients' quality of life by translating these motions into specific messages.

II. PROBLEM STATEMENT

As technology becomes increasingly integrated into daily life, IoT applications offer promising solutions for continuous monitoring and improved communication for paralysis patients.

Research by Ahmed Abdulkadir et al. (2017) highlighted the primary challenges faced by paralysis patients: mobility limitations and communication difficulties. These issues necessitate constant caregiver presence, particularly for elderly or critically ill patients. Additionally, the researchers noted that medical check-ups for paralyzed patients often involve costly procedures and diagnostics.

A study by Pranav et al. (2021) further explored the complexities of paralysis and the potential benefits of automated assistance systems. Their research revealed various types and degrees of paralysis, including partial, complete, permanent, temporary, flaccid, and spastic. Generalized paralysis can also be categorized based on the extent of bodily involvement: monoplegia, hemiplegia, diplegia, paraplegia, and quadriplegia. Some patients may experience speech impairment or partial paralysis, making consistent communication with caregivers challenging.

Building on these findings, a proposal emerged for an IoT-based healthcare system designed specifically for paralysis patients. This system aims to facilitate remote health monitoring and enable patients to communicate with caregivers through minimal hand movements. The design incorporates various hand gestures corresponding to different messages, such as emergencies, requests for food or water, or bathroom needs. An innovative feature of this system is the integration of home automation, allowing patients some control over their immediate environment, such as room lighting and fan operation.

The proposed system utilizes Wi-Fi, Bluetooth, and cellular connectivity to keep caregivers informed about patients' health status and needs. This comprehensive approach offers continuous, efficient, and cost-effective healthcare and assistance, potentially significantly improving the quality of life for paralysis patients.

III. OBJECTIVES

The aim of this project is to create an enhanced healthcare system for paralysis patients using IoT technology. The objectives include developing a wearable sensor-based device to help patients communicate through minimal hand movements, designing a system to monitor vital body parameters, transmitting this data wirelessly for remote monitoring via an IoT platform, and assessing the system's accuracy and efficiency through testing.

IV. JUSTIFICATION FOR THIS RESEARCH

The World Health Organization (2016) reports that elderly individuals, many of whom suffer from chronic conditions such as paralysis, require highly effective and efficient care solutions. The National Broadband Plan (2015) by the Federal Communications Commission (FCC) highlights that the adoption of remote patient monitoring through IoT technology could save the healthcare industry $700 billion over the next 15 to 20 years.

According to the US Paralysis Prevalence & Health Disparities Survey (2013), nearly 1 in 50 people, or approximately 5.4 million individuals, are living with paralysis, a number 40% higher than previous estimates. The rise in paralysis has led to a significant increase in the disabled population. Caregivers often need to provide constant attention, which can lead to physical and emotional exhaustion. The same survey found that around 41% of caregiver’s experience back problems, and about 28% of households with a paralyzed individual earn less than $15,000 annually.

A study by Akshay S. (2019) proposed a system to assist paralysis patients with remote health monitoring and communication using hand motions. However, the system faced several limitations, including imprecise data from sensors, leading to low accuracy. Future improvements suggested for this system include the integration of a GSM module for cellular communication via SMS and call alerts, the addition of more biosensors for reliable health monitoring, and the development of an app to allow caregivers and doctors to monitor the patient's health remotely at any time.

Given the high number of paralysis patients in society, the proposed design aims to address the shortcomings of existing systems and provide a more effective solution.

V. LITERATURE REVIEW

In relation to paralysis patients’ remote health monitoring and alert systems, various studies have explored IoT-based solutions. One system by Sujin et al. (2021) monitors vital signs such as heart rate, body temperature, and blood pressure. It uses biosensors to transmit health data to a static webpage accessible by caregivers. While this system provides essential health monitoring, it has limitations, such as relying on static web pages and lacking a wearable design. A more realistic solution would involve a mobile application and wearable devices. Additionally, gesture-controlled assistance could further improve patient care.

Similarly, Al Bassam et al. (2021) designed an IoT wearable device to monitor quarantined COVID-19 patients. Though effective in health monitoring, the system lacked a GSM module for communication during internet outages. This approach could be applied to paralysis patients, further enhanced with gesture-controlled devices.

Several other studies, including Prajoona et al. (2020) and Dahlia et al. (2020), introduced IoT-based health monitoring systems. These studies emphasized the importance of precise sensor data collection but pointed out limitations in the accuracy of sensors, the lack of mobile applications, and issues related to data security and connectivity. Future enhancements could include integrating GSM modules, improving sensor calibration, and adding more biosensors for comprehensive monitoring.

Various studies have developed systems enabling patients to perform simple tasks, such as switching on lights or fans, through hand gestures. For example, Prajakta et al. (2021) proposed a system using motion sensors and ESP-32 microcontroller for basic task automation. However, this system lacks a compact wearable device and has limited functionality, providing patients with minimal control. Future improvements could involve creating more versatile devices that allow better communication between patients and caregivers through minimal hand motion.

K. Vaishnavi et al. (2018) Developed a system using biosensors to measure heart rate, temperature, and humidity. The data was transmitted via Wi-Fi and Bluetooth. However, it lacked a GSM module and a mobile app. Ms.N.Renee et al. (2021) developed a system using sensors to detect hand movements and display messages. However, it lacked a GSM module and a mobile app.

VI. PROPOSED METHODOLGY

The proposed methodology for IoT based paralysis patient healthcare system is explained in-depth with the aid of overall system block diagram in Fig. 1.

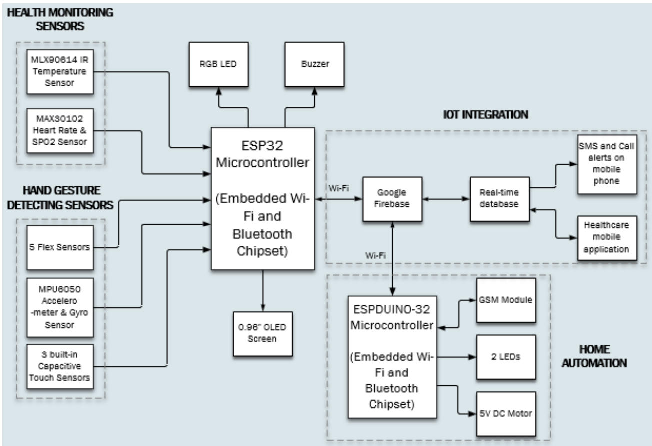

Fig. 1. Overall Block Diagram

Starting from the left side, the network of sensors is divided into two categories, health monitoring sensors and hand gestures detecting sensors. The health monitoring sensors, including the MLX90614 and MAX30102 sensors, are used to measure the body vitals of the paralysed patient. While the hand gestures detecting sensors, including flex, MPU6050 and in-built capacitive touch sensors, are used to record the fingers and hand movement of the paralysed patient to perform various functions. All these sensors act as the input devices for the system, which are then interfaced with the ESP-32 microcontroller. The readings measured by the sensors are transmitted to the ESP-32 for data processing and analysing. Since the ESP-32 has the Wi-Fi capability, therefore it creates an IoT environment to send the data wirelessly for remote monitoring.

The output devices interfaced with the ESP-32 microcontroller includes an OLED display screen, buzzer and RGB LED light. The OLED screen is used to display the patient’s body vitals and message status so that the caretaker, who is in the proximity to the patient, can monitor it on spot. On the other hand, the buzzer and RGB LED are used to notify and indicate the caretaker about patient's special needs or in case of an emergency.

The next block of the system is based on the IoT integration, including wireless communication, real-time database, and mobile application. The ESP-32 is programmed to send the data continuously to the Google Firebase's server through REST APIs and the data transmission is done between both the platforms through HTTP requests. The data coming from the ESP-32 is stored into the real-time database of the Google Firebase, from where it then sends it to the mobile application for display. The mobile application is designed using the MIT App Inventor low-code platform. All the patient's vitals, including the emergency alerts and patient's special needs are displayed in real-time, so they can be monitored every time through distance.

The last part of this system is the home automation, which is achieved through an additional circuit built specifically for this purpose. The ESPDUINO-32 microcontroller is used to control the LEDs and a DC Motor. The LEDs represent the lights in the room, while the DC motor represents the fan. The values that are uploaded in the real-time database from the hand gesture detecting sensors in the smart glove are then sent to the ESPDUINO-32 microcontroller. Based on the specific sensor values, which are generated due to specific hand gestures, the LEDs and DC motor are turned on and off. This way, the paralysed patient can control the room's lights and fan through hand gestures wirelessly. Furthermore, the GSM module has been linked with the microcontroller for cellular communication through SMS notifications and call alerts.

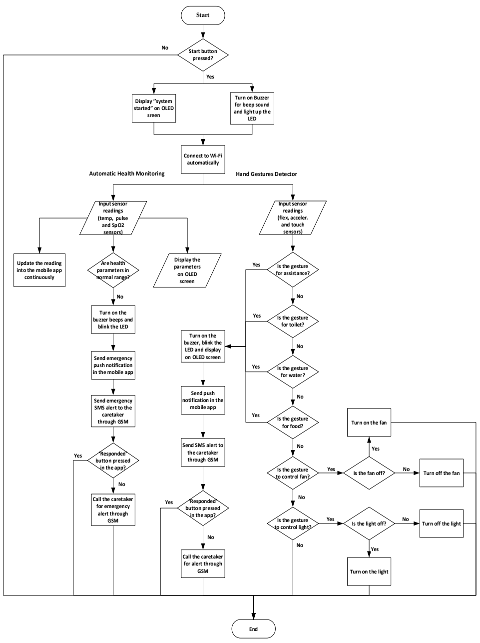

Fig. 2. System Flowchart

The overall flowchart of the system is shown in Fig. 2. The system starts by switching on the power button. Upon boot up, the OLED screen displays 'system started' message, the buzzer produces the beep sound, and the LED indicator lights up. The microcontroller gets connected to the Wi-Fi network automatically. The later part of the system flow divides into two parts, automatic health monitoring and hand gestures detector.

The automatic health monitoring system inputs the data from the IR temperature sensor, heart rate sensor and SpO2 sensor. The readings are not only displayed on the OLED screen, but the data is continuously updated in the mobile app through internet connectivity. The system is able to monitor the patient's health all the time. If the body's vital parameters are not within the normal range, then the system goes into emergency mode. First of all, it produces beep sounds through the buzzer and blinks the LED. The emergency notification is popped up in the mobile application so the caretakers can be notified. Simultaneously, the caretaker and medical staff is notified about the patient's health through cellular SMS alerts. The caretaker needs to press the 'responded' button in this case, so that the patient knows that the message has been delivered through beep sounds and LED indication. For instance, the responded button is not pressed for some time, then the system calls the caretaker or doctor for informing.

The hand gesture detecting system inputs the data from the flex sensors, accelerometer sensors and touch sensors. The system continuously measures and detected the finger movements of the patient. There are some pre-set readings from the sensors stored in the system that corresponds to the specific gestures. There are different hand movements for different messages. For example, there is a hand gesture for the case where patient wants some assistance from the caretaker or go to the toilet. Moreover, the patient can communicate with the caretaker for special needs such as food or water. Therefore, the system detects the specific gesture and based on that it not only displays the message on the OLED screen, produce beep sounds and blinks the LED but is also sends the in-app notification and cellular SMS alert to the caretaker. On the other hand, the patient can also control the room fan and light through specific gestures.

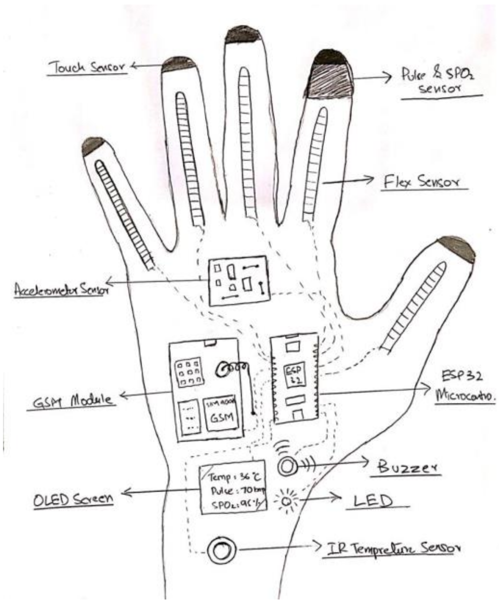

Fig. 3. Smart Glove 2D Sketch

The design of the wearable device is basically a smart glove. The smart glove is embedded with all the sensors required to sense the body's vital health parameters along with the sensors used to measure and detect the hand gestures. All the sensors are placed on the specific places as per their functionality. The sensors are linked with microcontroller, that is places at the back side of the hand. Fig. 3. shows the 2D sketch of the wearable smart glove.

VII. Results and Discussion

The overall system includes both the hardware and software. The hardware side of the system consists of the main hardware, the smart glove, and additional circuit for room automation. On the other hand, the software side of the system consist of the patient's health portal, which is basically a mobile application for both Android and iOS.

As mentioned earlier, the smart glove consists of several sensors for both patient's health monitoring and hand gesture detection. Moreover, the output devices included in the prototype are OLED display, buzzer and RGB LED. All the components have been interfaced with the ESP-32 microcontroller, which has the built in Wi-Fi capability. The Fig. 4. shows the circuit diagram of the smart glove.

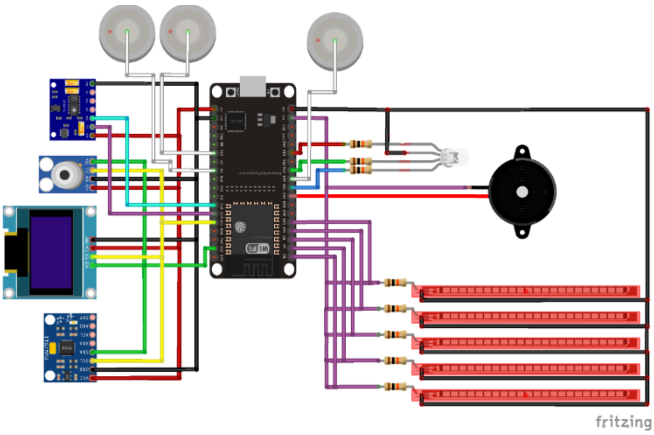

Fig. 4. Smart Glove Circuit Diagram

As seen in Fig. 4., there are five flex sensors used in the smart glove, one for each finger. The flex sensors are placed on the front side of each finger, which will then help in detecting the movement of the fingers. The bending of the fingers results in bending of the flex sensors, thus changing its resistance value. Furthermore, one MPU6050 accelerometer and gyro sensor is placed on the palm to detect its rotation in all axes.

On the other hand, a MLX90614 infrared temperature sensor is used in the smart glove for contactless measuring of the patient's body temperature. To measure the heart rate and oxygen saturation of the patient, MAX30102 sensor is placed on the index finger. Three in-built touch capacitive sensors of the ESP-32 microcontroller are used to detect the touch sensitivity. Each touch capacitive sensor pin is connected with the foil paper and the foil paper is attached on the tip of the last three fingers.

The additional components added in the circuitry act as the output devices to the system. The 0.96 inches OLED screen is used to display the patient's details including its body vitals and status. A buzzer and RGB LED are used as the indication devices to alert the nearby caretaker if the patient needs any assistance or if there is an emergency. Each flex sensor is connected with the 10k ohms resistor, while 220 ohms resistors are used for the LED.

All the components are interfaced with the different pins of the microcontroller. As there are two different I2C interfaces established in the ESP-32 microcontroller, the MPU6050, MAX30102, MLX90614 and OLED screen are all using I2C communication and are powered by 3.3 volts. In I2C communication protocol, there is one SDA (data line) pin and one SCL (clock line) pin. On the other hand, the flex sensors are connected with the analogue input pins of the microcontroller through 10k ohms resistors and are powered by 5 volts. The buzzer and RGB LED are interfaced with the digital output pins of the microcontroller and powered by 5 volts as well. As mentioned earlier, the foil papers are linked with the in-built touch capacitive pins of the ESP-32 microcontroller.

Fig. 5. Smart Glove Final Design (Back)

Fig. 5. shows the final design of the smart glove from the front side. As mentioned earlier, the patient hand would be kept in a position where the palm would be facing upwards. Therefore, all the main components are placed on the palm side. The reason is because naturally humans tend to keep the hand position in that way. Moreover, this hand position is more comfortable as the hand movement and finger bending is much more convenient.

The flex sensors are placed on each finger, so the movement of can be recorded. Furthermore, the last three fingers have foil papers on their tips, which are acts as the touch sensors. Therefore, the tip of the thumb is kept naked so when it comes in contact with the touch sensors, the system will detect it and perform a certain function. The MAX30102 heart rate and oxygen saturation sensor is placed on the index finger. After the glove is worn, the strap on the index finger is tightened in order to fix its position and apply more pressure on the finger so it can measure the heart rate and SpO2 accurately.

As shown in Fig. 6., the MPU6050 is placed on the palm on the straight position and is calibrated to be on the vertex. From this position, it will detect the movement of the palm in all the 6 axes (± x, ± y and ± z axes). Moreover, the MLX90614 IR temperature sensor is also placed in the middle of the palm and is facing towards the palm so the body temperature can be measured continuously. There is a plastic hood connected with the temperature sensor for better measurement. The OLED screen is placed below the sensors, which displays the patient's details including its body vitals. The RGB LED light is kept right beside the OLED screen for indication.

Fig. 6. Smart Glove Final Design (Front)

The additional hardware developed for the paralysis patient healthcare system is not related to the main system. It is just a simple secondary circuit constructed to represent the lights and fan in the patient's room. Therefore, through room automation, the paralysis patient can directly control the lights and fan in their room by doing specific hand gesture commands while wearing the smart glove. The Fig. 7. shows the circuit construction for the room automation on breadboard. The ESPDUINO-32 microcontroller board has been used to control the two LEDs and one DC motor. The green LED represents the room's main light, while the red LED represents the room's night light. On the other hand, the DC motor represents the ceiling fan.

Fig. 7. Room Automation Hardware

The aim of the project is to enable remote health monitoring for the paralysis patients and provide them assistance through gesture-controlled communication. To fulfil one of the objectives of this project, a patient health portal is developed in form of a mobile application through MIT App Inventor platform. The MIT App Inventor is a low-code mobile application development platform that uses drag-and-drop block coding. The Fig. 8. shows the login page of the patient healthcare portal.

Fig. 8. Patient Helath Portal Login Page

When the correct login credentials are entered, the user will be allowed to access the patient's details in the healthcare portal. Fig. 9. shows the second page of the mobile application, which contains information related to the patient and room. First, the patient's personal details are displayed including its name, age, sex, and condition. Next, the patient's body vitals including body temperature, heart rate and SpO2 are continuously updated every second.

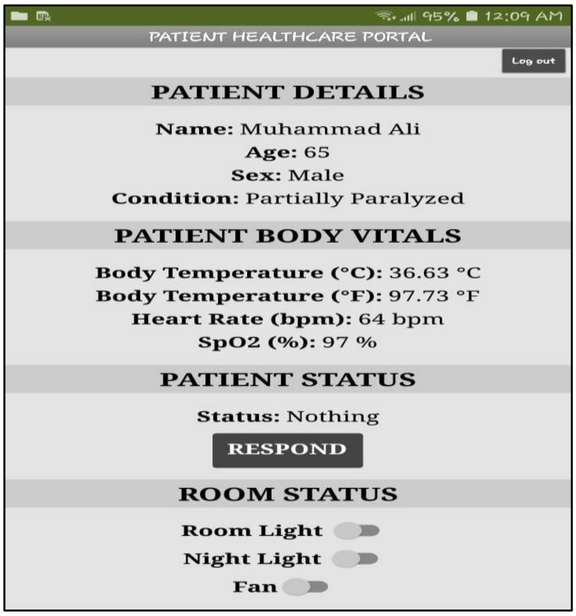

Fig. 9. Patient Helath Portal Patient Detail Page

Furthermore, the patient's status message is also displayed on the screen, which is useful for the caretakers to get notified of the patient's status remotely. The 'Respond' button is added in the interface, which turns green whenever there is a message from the paralysis patient. This would send the alert push-notifications continuously on the phone for immediate attention. Once the caretaker is aware of the patient's status, he or she can press the 'Respond' button, that would send the system back to its normal state as the patient has been responded.

Additionally, the room status is also displayed at the bottom of the screen. This way, the caretaker can be notified of the room light, night light and fan status. Whenever the paralysis patient controls the room appliances through hand gesture, it would be updated in the health portal. Moreover, the caretaker can also choose to control the room appliances remotely by themselves through the mobile application. The patient's body vitals and room status displayed in the patient health portal are retrieved from the Google Firebase's real-time database.

VIII. Conclusion

To conclude up, an IoT based paralysis healthcare system will be designed and implemented through this project. The project is divided into 2 phases, investigation, and implementation phase. This report is focusing on the first phase which is the investigation phase. Moreover, through this investigation report a brief introduction was stated about the topic, followed by stating the project main aim, objectives, and justification. Furthermore, the main research problem that had been mentioned is the disability of the paralysis patient, due to which they cannot communicate. Through this project, the problem is solved through the development of smart wearable glove, that not only monitors the patients' health but also provide them assistance.

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