IOT BASED HEALTHCARE SYSTEM FOR PARALYZED INDIVIDUALS: REAL TIME MONITORING, VOICE CONTROL, AND ALERT MECHANISMS

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GENERAL INFORMATION

Received date: 10/01/2025

Revised date: 22/04/2025

Accepted date: 03/07/2025

KEYWORD

IoT based Healthcare;

Paralyzed Individuals;

Real time Monitoring.

ABSTRACT

This paper study an IoT based healthcare system designed for paralyzed individuals, integrating real time monitoring of vital health and environmental parameters, voice controlled functionalities, and multi channel alert mechanisms. The system leverages sensors such as MAX30102, DHT11, and MQ 135 to measure SpO2, heart rate, temperature, humidity, and air quality. Voice control enhances user independence, while alert systems ensure timely caregiver intervention. Experimental results demonstrated high accuracy, reliability, and user satisfaction. Despite limitations like sensor latency and reliance on stable Wi Fi, the system offers a scalable and cost effective solution, addressing critical gaps in caregiving and improving quality of life for users.

1. INTRODUCTION

Recently, particularly in the field of the Internet of Things (IoT), have opened new possibilities for healthcare innovation (Moorthi et al., 2023). Among the many beneficiaries of these advancements are individuals with paralysis, who require constant monitoring and assistance due to their limited mobility and heightened vulnerability to health complications (Iqbal et al., 2021). As the prevalence of paralysis increases due to factors such as accidents, illnesses, and aging, the demand for efficient and cost effective caregiving solutions has become more pressing. This growing need highlights the potential of IoT based systems to revolutionize healthcare for individuals with disabilities (Rafid et al., 2023).

The ranging from difficulties in performing basic tasks to the risk of serious health conditions. These challenges include pressure ulcers from prolonged immobility, injuries from falls, and undetected chronic health issues (Aldousari et al., 2023). While traditional caregiving methods provide valuable support, they often lack the precision, automation, and scalability needed to comprehensively address these issues. Existing assistive technologies, though beneficial, are frequently constrained by high costs, limited integration, and insufficient user centric designs (Jacob et al., 2021).

This paper study an IoT based healthcare monitoring and assistance system specifically designed for individuals with paralysis. The system incorporates real time monitoring of vital health indicators such as blood oxygen saturation (SpO2), heart rate, ambient temperature, humidity, and air quality (Jadhav et al., 2021). It also features voice controlled functionalities, enabling users to operate essential devices independently and improving their quality of life. Moreover, the system includes automated alert mechanisms that notify caregivers of potential health risks, ensuring timely intervention and enhanced safety for users (Chowdhury et al., 2024).

The objectives of this study are threefold. First, it seeks to highlight the critical need for IoT based solutions in healthcare for paralyzed individuals (Eshrak et al., 2023). Second, it analyzes existing IoT applications in healthcare to identify best practices and common challenges. Finally, it proposes a comprehensive IoT solution that integrates health monitoring, automated alerts, and voice control capabilities to address the specific needs of paralyzed users. By leveraging IoT technologies, this research aims to contribute to a more accessible and efficient healthcare system, improving outcomes for individuals with paralysis and reducing the caregiving burden on families and healthcare providers (Anirudh et al., 2023).

2. RELATED WORKS

The integration of IoT in healthcare has gained significant attention in recent years, particularly in addressing the needs of individuals with chronic conditions or disabilities (Basinayak et al., 2024). Numerous studies and applications have demonstrated the potential of IoT to enhance healthcare monitoring, automate caregiving processes, and improve patient outcomes (Mnaathr, 2023). This section reviews existing IoT based healthcare systems, focusing on their capabilities, limitations, and relevance to supporting paralyzed individuals (Kumar et al., 2021).

IoT based health monitoring systems are designed to continuously track vital parameters such as heart rate, blood oxygen saturation (SpO2), and body temperature (Selvarani, 2024). These systems typically use advanced sensors, such as the MAX30102, to measure SpO2 and heart rate, providing real time data for healthcare professionals and caregivers. Such applications are crucial for early detection of health risks, including hypoxia and irregular heart rhythms. However, many of these systems lack the integration of multiple health indicators, such as environmental factors, which are critical for paralyzed individuals (Annepu et al., 2023).

The health monitoring by IoT systems often incorporate environmental sensors to assess conditions such as temperature, humidity, and air quality. Sensors like the DHT11 and MQ 135 are commonly used to monitor environmental parameters, ensuring that the living environment is conducive to the health and comfort of users (S et al., 2023). However, despite their potential, many existing systems are limited in their ability to provide actionable insights or proactive interventions based on environmental data (Usha et al., 2023).

Voice controlled IoT systems have also emerged as a valuable tool for enhancing independence among individuals with disabilities (HemanthKumar., 2021). Platforms like Sinric Pro, integrated with assistants such as Google Assistant or Amazon Alexa, enable users to control household devices like lights and fans through voice commands. While these systems offer a significant improvement in user autonomy, their reliance on stable internet connections and compatibility issues with certain hardware components can limit their effectiveness in real world scenarios (Sujin et al., 2021).

The challenges remain in developing a comprehensive IoT solution tailored to the specific needs of paralyzed individuals. Many existing systems are standalone, focusing on either health monitoring or environmental control, without providing a unified platform for seamless integration (Makanyadevi et al., 2024). Moreover, the high costs and complexity of implementing such systems often pose barriers to widespread adoption, particularly in low resource settings. This paper builds upon the lessons learned from existing IoT applications, addressing their limitations by proposing a holistic system that integrates health monitoring, environmental assessment, and voice controlled functionalities. By leveraging low cost sensors, robust alert mechanisms, and user friendly interfaces, the proposed solution aims to fill the gaps identified in current systems and provide a scalable, practical approach to supporting individuals with paralysis (Arunsankar et al., 2023).

3. METHODOLOGY

This study focuses on the development of an IoT based healthcare system designed to address the specific needs of individuals with paralysis. The methodology encompasses the design and architecture of the system, integration of sensors for health and environmental monitoring, voice controlled functionalities, data processing, and an alert mechanism for timely intervention. By leveraging low cost and accessible technologies, the system is aimed at improving the quality of life for paralyzed individuals while alleviating the caregiving burden on families (P, 2024).

The system architecture is designed as a multi functional platform that integrates health monitoring, environmental assessment, and voice controlled operations. The core components include IoT sensors for data collection, an ESP8266 microcontroller for processing and transmitting data, an alert system for notifying caregivers, and a voice control module for enabling independent operation of household devices. This modular design ensures scalability, affordability, and ease of implementation (Usha et al., 2023).

A range of sensors is employed to monitor both physiological and environmental parameters. The MAX30102 sensor measures blood oxygen saturation (SpO2) and heart rate using optical technology, providing real time health data. The DHT11 sensor monitors ambient temperature and humidity to ensure a comfortable living environment, while the MQ 135 sensor detects air quality by identifying harmful gases and pollutants. These sensors are connected to the ESP8266 microcontroller, which gathers and processes data at regular intervals. Calibration and testing are performed to ensure the sensors provide accurate and reliable readings under various conditions. The System connection diagram shown in Figure 1

The system incorporates voice controlled functionalities using the Sinric Pro platform. This feature allows paralyzed individuals to operate devices such as fans and lights through voice commands, linked to Google Assistant. Devices are connected to the ESP8266 microcontroller via relay modules, enabling seamless on/off control. The voice control system is optimized for fast response times and user friendly interaction, significantly improving the autonomy of individuals with paralysis. Data collected by the sensors is processed locally on the ESP8266 and transmitted to the cloud for storage and visualization. The system integrates with Google Sheets API, allowing data to be stored in real time and visualized through charts and graphs. This enables caregivers to track health and environmental trends over time. The data can also be exported to Excel for further analysis, providing actionable insights for long term healthcare management.

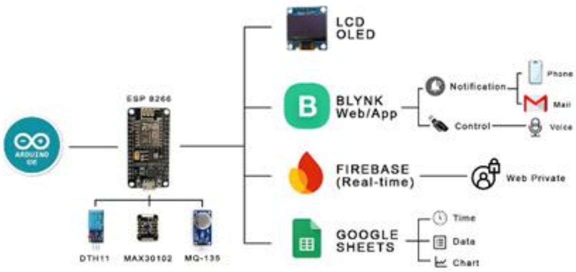

Figure 1. System connection diagram

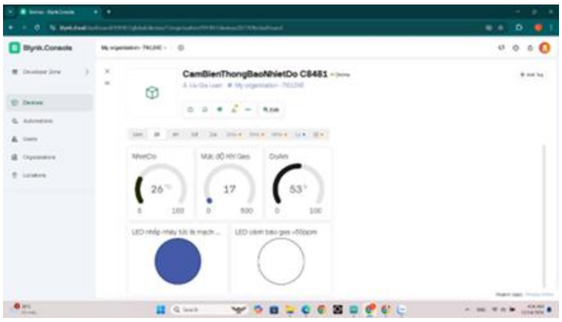

Figure 2. Control interface on the online system

The system features a robust alert mechanism to notify caregivers of critical conditions. Threshold based alerts are triggered when parameters such as SpO2, heart rate, temperature, humidity, or air quality deviate from safe limits. Multi channel notifications, including mobile applications, SMS, email, and local alarms, ensure that caregivers receive timely alerts, even in remote settings. Users and caregivers can customize thresholds and notification preferences based on individual needs, enhancing the system's adaptability.

Given the sensitive nature of health related data, the system incorporates basic data security mechanisms to ensure secure transmission and storage. Communication between the ESP8266 microcontroller and the Google Sheets platform is conducted via HTTPS, which provides encryption during data transfer to prevent eavesdropping and man-in-the-middle attacks. The use of HTTPS ensures that SpO2 levels, heart rate, and other personal data are not transmitted in plaintext over the internet.

In addition to secure channels, access to the Google Sheets where the data is stored is restricted via authentication mechanisms, such as OAuth 2.0. Only authorized users with proper credentials can view or edit the health data, ensuring data confidentiality. Moreover, API keys and tokens are stored securely and not hard-coded within the firmware to prevent unauthorized access in the event of device compromise. Future iterations of the system may include more advanced security features, such as end-to-end encryption, token-based user authentication, and integration with healthcare data privacy standards like HIPAA or GDPR, especially for deployments in regions where such regulations apply. Comprehensive testing and evaluation are conducted to ensure the system's reliability and usability. Functional testing verifies the accuracy of sensors and responsiveness of the voice control module, while non functional testing assesses system stability, data transmission speed, and battery life. User acceptance testing involves feedback from caregivers and individuals with paralysis to evaluate the system's effectiveness in real world scenarios

4. EXPERIMENTAL RESULTS

The proposed IoT based healthcare system was implemented and tested to evaluate its performance in real world scenarios. The system's key components sensors, voice control module, data transmission, and alert mechanism were assessed for accuracy, reliability, and usability. The results are summarized in Table 1, followed by detailed explanations.

The system's sensors exhibited high accuracy and reliability. The MAX30102 sensor effectively measured SpO2 levels and heart rate, with deviations of less than 2% compared to commercial medical devices. Environmental sensors, including the DHT11 for temperature and humidity and the MQ 135 for air quality, provided consistent and accurate data. The DHT11 showed minor latency of 1–2 seconds during abrupt changes in temperature or humidity, while the MQ 135 effectively identified variations in air quality, shown in Figure 3.

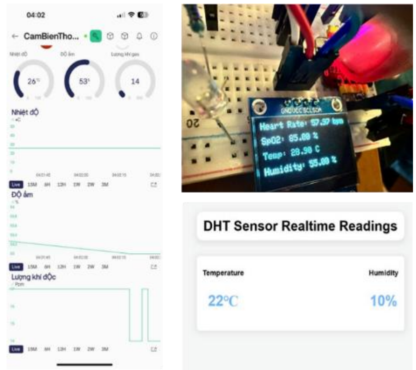

Figure 3. Data collected by sensors

Table 1. The testing results

Parameter - Sensor/ Module	Blood Oxygen Saturation (SpO2) – MAX30102	Heart Rate - MAX30102	Temperature - DHT11	Humidity - DHT11	Air Quality - MQ 135	Voice Control - Sinric Pro + ESP8266	Data Transmission - ESP8266 + Google Sheets	Data Visualization - Google Sheets	Alert Mechanism - Multichannel (app, SMS)	System Stability - ESP8266
Test Results	Measured SpO2 within 95%–100% in healthy individuals; triggered alerts below 90% during testing (Accurate with deviations < 2%).	Recorded heart rate of 60–100 bpm with < 2 bpm deviation compared to commercial devices (Reliable with consistent accuracy).	Measured 20°C–35°C with minor latency during abrupt changes of 1–2 seconds (Accurate but minor delay in dynamic environments).	Measured 40%–60% relative humidity; stable performance (Reliable for general environmental conditions).	Detected VOC fluctuations effectively; alerts met thresholds during simulated pollution events (Effective in identifying air quality changes).	Response time: 1–2 seconds; accuracy: 98% in quiet environments, 92% in moderate noise (High accuracy; slight reduction in noisy settings).	Data transmitted every 10 seconds with no packet loss (Reliable for real time monitoring).	Data visualized effectively with trend analysis and exported to Excel (Facilitated caregiver understanding).	Notifications via app, SMS, and email delivered within 2 seconds; on site alarms effective (Ensured timely caregiver intervention).	Maintained stable operation; auto reconnected to Wi Fi during disruptions (High reliability for extended operation).

Sensor Performance

Voice Control Functionality

The voice control module, utilizing Sinric Pro and ESP8266, performed efficiently. The system responded to voice commands within 1–2 seconds on average, with an accuracy rate of 98% in quiet environments and 92% in moderately noisy settings. However, performance slightly declined in highly noisy environments, where accuracy dropped to 85%. Despite this, the feature was well received by users, as it significantly enhanced their independence, shown in Figure 4.

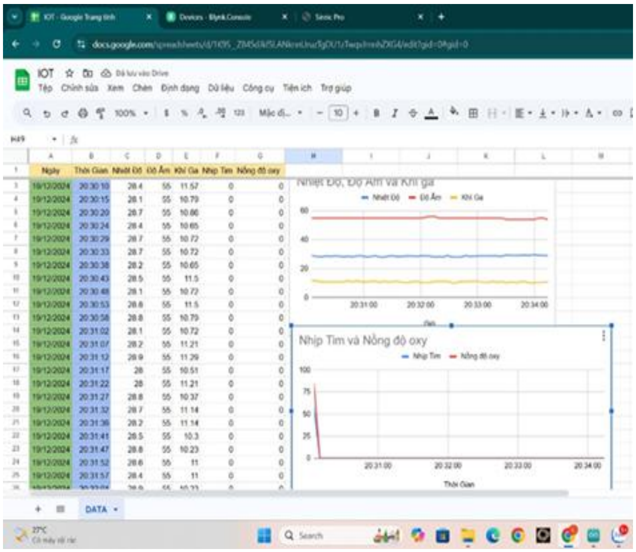

Figure 4. Control the system by voice

Data Transmission and Visualization

Data transmission through the ESP8266 and Google Sheets API was stable and reliable. Sensor data was transmitted every 10 seconds with no packet loss, ensuring continuous monitoring. Visualization in Google Sheets allowed caregivers to track health and environmental trends over time, and exporting data to Excel provided additional analysis options. The integration of real time data visualization proved valuable for long term healthcare planning, shown in Figure 5.

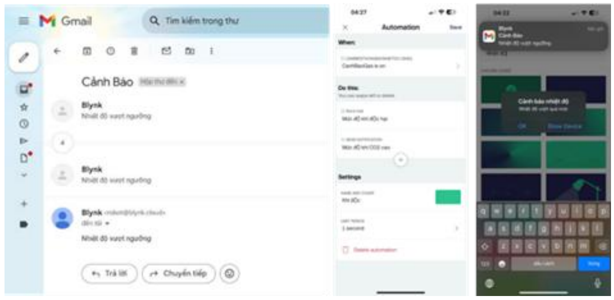

Figure 5. Time, Data and Charts

Alert Mechanism

The multi channel alert system delivered notifications promptly, with a delay of less than 2 seconds. Notifications were sent through mobile applications, SMS, email, and on site alarms. Caregivers praised the effectiveness of the alerts, which ensured timely interventions during emergencies. Customizable thresholds further enhanced the system's adaptability to individual user needs, shown in Figure 6.

Figure 6. Warnings are set for the system

The experimental results demonstrate that the IoT based healthcare system is effective in monitoring vital health and environmental parameters, supporting voice controlled device operations, and providing timely alerts. The system's stability, accuracy, and user friendly design make it a practical and scalable solution for improving the quality of life of paralyzed individuals and reducing the burden on caregivers.

5. DISCUSSION

The experimental results of the proposed IoT based healthcare system highlight its effectiveness in addressing the unique needs of paralyzed individuals. By integrating advanced sensors, voice controlled functionalities, and robust alert mechanisms, the system successfully bridges critical gaps in traditional caregiving methods. The accurate monitoring of health parameters such as SpO2 and heart rate, coupled with environmental monitoring for temperature, humidity, and air quality, provides a comprehensive approach to healthcare management. These features not only enhance the safety and comfort of users but also reduce the reliance on constant caregiver supervision, allowing for more efficient resource allocation in caregiving.

The inclusion of voice controlled functionalities significantly improves the independence and quality of life for users. Paralyzed individuals can operate essential devices such as lights and fans using simple voice commands, empowering them to perform basic tasks without assistance. This feature, combined with the system's integration with platforms like Google Assistant, ensures ease of use and accessibility, making it a practical solution for individuals with mobility limitations. Caregivers also benefit from the multi channel alert mechanism, which provides real time notifications via mobile applications, SMS, email, and on site alarms. This comprehensive approach ensures that caregivers are promptly informed of any abnormal health or environmental conditions, enabling timely intervention during emergencies.

While the current implementation uses HTTPS for secure data transmission and basic authentication mechanisms to limit access to cloud storage, there remains room for improvement. Advanced threats such as API hijacking, device spoofing, or unauthorized access to data logs are potential risks. To address this, future system designs should explore the integration of stronger encryption protocols, device-level authentication, and periodic token renewal strategies. Additionally, encrypting data at rest on cloud platforms and ensuring compliance with healthcare data protection regulations would further enhance user trust and system integrity.

The system has limitations that warrant further consideration. The DHT11 sensor, while cost effective, exhibited minor latency in detecting abrupt changes in temperature and humidity. Replacing it with a more advanced sensor, such as the DHT22, could improve both accuracy and response time. Additionally, the voice control feature faced challenges in noisy environments, with recognition accuracy dropping to 85%. Integrating noise cancellation algorithms or more sophisticated natural language processing (NLP) techniques could mitigate this issue, enhancing the reliability of the system under varying environmental conditions.

Another limitation of the system is its reliance on stable Wi Fi connectivity for data transmission and voice control operations. In regions with poor internet access, the system's performance may be compromised, reducing its reliability. Future iterations of the system could incorporate offline capabilities or alternative communication methods, such as Bluetooth or Zigbee, to ensure consistent functionality even in areas with unstable connectivity.

6. CONCLUSION

This study demonstrated the development and implementation of an IoT based healthcare system tailored to the needs of paralyzed individuals. The system integrates advanced sensors, voice controlled functionalities, and real time alert mechanisms to provide comprehensive health and environmental monitoring, promote user independence, and enhance caregiver support. Through experimental testing, the system demonstrated its effectiveness in accurately measuring vital health parameters such as SpO2 and heart rate, as well as environmental factors like temperature, humidity, and air quality. Additionally, the voice control feature allowed users to perform basic tasks independently, significantly improving their quality of life.

The multi channel alert mechanism proved invaluable for ensuring timely caregiver intervention during emergencies. Notifications via mobile applications, SMS, email, and on site alarms minimized the risk of missed alerts and enhanced the safety and well being of users. The system's modular design, affordability, and scalability make it a practical solution for healthcare applications, particularly for individuals with limited mobility.

However, the study also highlighted areas for improvement. The limitations related to sensor latency, voice recognition in noisy environments, and reliance on stable Wi Fi connectivity underscore the need for ongoing refinement. Future iterations of the system can address these challenges by incorporating advanced sensors, noise cancellation algorithms, and alternative communication technologies. Integrating machine learning for predictive analytics and adding features like fall detection can further expand the system's functionality.

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HỆ THỐNG CHĂM SÓC SỨC KHỎE DÀNH CHO NGƯỜI BẠI LIỆT BẰNG THIẾT BỊ IOT: THEO DÕI THỜI GIAN THỰC, ĐIỀU KHIỂN BẰNG GIỌNG NÓI VÀ CƠ CHẾ CẢNH BÁO

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THÔNG TIN CHUNG

Ngày nhận: 10/01/2025

Ngày sửa đổi: 22/04/2025

Ngày duyệt đăng: 03/07/2025

TỪ KHÓA

Chăm sóc sức khỏe dựa trên IoT;
Người bại liệt;
Theo dõi thời gian thực.

TÓM TẮT

Bài báo này nghiên cứu một hệ thống chăm sóc sức khỏe dựa trên IoT dành cho những người bị liệt, tích hợp giám sát thời gian thực các thông số sức khỏe và môi trường, các chức năng điều khiển bằng giọng nói, cùng cơ chế cảnh báo đa kênh. Hệ thống sử dụng các cảm biến như MAX30102, DHT11, và MQ-135 để đo SpO2, nhịp tim, nhiệt độ, độ ẩm và chất lượng không khí. Điều khiển bằng giọng nói giúp tăng tính tự chủ cho người dùng, trong khi hệ thống cảnh báo đảm bảo người chăm sóc có thể can thiệp kịp thời. Kết quả thực nghiệm cho thấy độ chính xác, độ tin cậy và mức độ hài lòng của người dùng đều cao. Mặc dù còn tồn tại một số hạn chế như độ trễ của cảm biến và sự phụ thuộc vào kết nối Wi-Fi ổn định, hệ thống vẫn mang lại giải pháp có khả năng mở rộng, chi phí hiệu quả, góp phần khắc phục những thiếu sót quan trọng trong chăm sóc và nâng cao chất lượng cuộc sống cho người dùng.