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Research Article

IoT-Based Smart Wheelchair for Assisted Mobility and Safety Monitoring

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Abstract

Mobility impairment significantly affects the independence and quality of life of elderly individuals and people with physical disabilities. Conventional wheelchairs require manual assistance and offer limited safety and monitoring features. Recent advancements in the Internet of Things (IoT) have enabled the development of smart wheelchairs that integrate autonomous navigation, obstacle detection, and health monitoring.

This paper presents the design and implementation of an IoT-based smart wheelchair that assists users through obstacle avoidance, remote monitoring, and emergency alert generation. The system integrates ultrasonic sensors for obstacle detection, an ESP32 microcontroller for processing and communication, and IoT connectivity for real-time monitoring via a mobile application. Health parameters and emergency alerts are transmitted wirelessly to caregivers. Experimental results demonstrate reliable navigation, low-latency communication, and improved user safety. The proposed system is cost-effective, scalable, and suitable for indoor and semi-outdoor environments, making it a practical solution for assisted mobility applications. This work highlights the potential of IoT technology in improving public health protection and sustainable development aligned with the Government of India guidelines.

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KEYWORDS: IoT, Smart Wheelchair, Assistive Technology, Obstacle Detection, ESP32.

1. INTRODUCTION

Mobility is a fundamental human need that directly impacts independence and quality of life. According to the World Health Organisation, over 75 million people worldwide require wheelchairs for mobility assistance, and this number continues to rise due to ageing populations and increased incidence of physical disabilities [6].

Traditional wheelchairs are either manual or joystick-based, requiring continuous human effort or caregiver assistance. These systems lack safety mechanisms such as obstacle detection, emergency alerts, and remote monitoring, which are critical for independent mobility [1], [7].

Recent developments in Internet of Things (IoT) technology have enabled smart assistive devices capable of real-time sensing, wireless communication, and intelligent decision-making [2], [15]. Smart wheelchairs integrate sensors, microcontrollers, and wireless networks to enhance navigation, safety, and user interaction [3], [9].

This paper presents an IoT-based smart wheelchair system designed to provide obstacle avoidance, emergency alerting, and remote monitoring using ESP32 and cloud integration. The objective is to enhance user independence, safety, and accessibility while maintaining affordability and scalability.

2. LITERATURE REVIEW

Researchers have proposed various smart wheelchair systems using IoT and embedded technologies to improve assisted mobility. Kumar et al. (2022) developed an ultrasonic-based smart wheelchair for indoor navigation using Bluetooth communication. While effective in obstacle detection, the system had a limited range and lacked remote monitoring capabilities [1]. Liu et al. (2022) proposed a smart wheelchair integrating gesture control, GPS, and IMU sensors for enhanced human–machine interaction. Although the system improved usability, it increased system complexity and cost [2].

Rahman et al. (2023) presented an EEG-controlled smart wheelchair integrated with IoT for healthcare monitoring. The system enabled brain-signal-based navigation but required complex signal processing and calibration [3].

Cui et al. (2024) implemented an outdoor smart wheelchair using sensor fusion and cost-map-based navigation. The system achieved accurate localisation but faced challenges in dynamic outdoor environments [4].

Khan et al. (2024) developed a voice-controlled wheelchair with IoT-based home automation. While voice control enhanced accessibility, system performance was sensitive to environmental noise [5].

These studies indicate the need for a reliable, low-cost smart wheelchair with integrated obstacle detection, real-time monitoring, and emergency alert mechanisms, which the proposed system aims to address.

3. METHODOLOGY

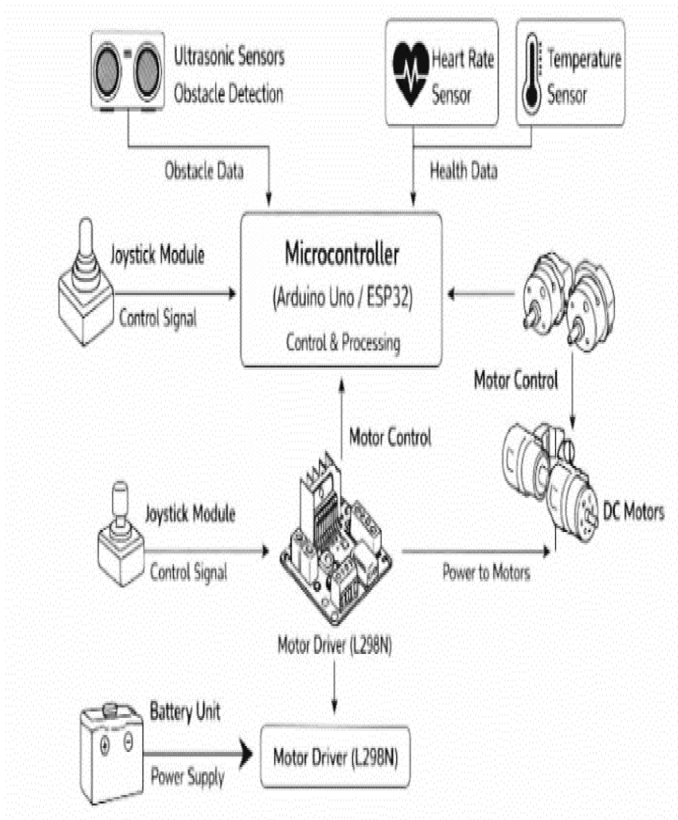
The proposed smart wheelchair system integrates sensing, processing, and communication modules to provide assisted navigation and safety monitoring.

A. System Architecture

The system consists of ultrasonic sensors for obstacle detection, an ESP32 microcontroller for data processing and communication, motor driver circuitry for motion control, and IoT connectivity for remote monitoring. Data is transmitted wirelessly to a mobile application for real-time visualisation and alerts, as shown in Figure 1 and Figure 2.

B. Block Diagram

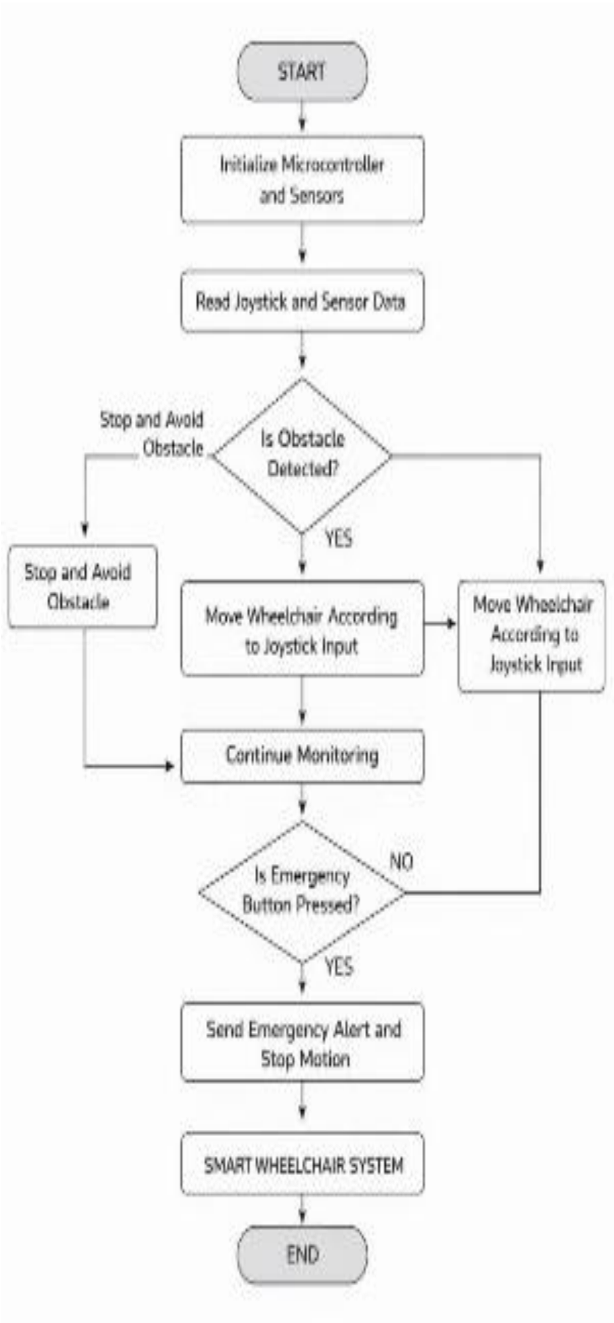
Figure 1: Block diagram of the smart wheelchair system



This block diagram represents the hardware architecture of the presented system. The smart wheelchair system is controlled by a microcontroller (Arduino Uno/ESP32), which acts as the central processing unit. Ultrasonic sensors are used to detect obstacles and prevent collisions during wheelchair movement. A joystick module allows the user to manually control the direction and speed of the wheelchair. The motor driver (L298N) interfaces between the microcontroller and DC motors to control motion. DC motors provide the mechanical propulsion required for wheelchair movement. Health monitoring sensors, such as heart rate and temperature sensors, continuously track user health parameters. A battery unit supplies regulated power to all system components, ensuring reliable operation.

C. Flow Chart

Figure 2: Flow chart of smart wheelchair operation



This flowchart illustrates the working of the proposed system. The process begins by initialising the microcontroller and all connected sensors. The system continuously reads joystick inputs and sensor data. Ultrasonic sensors check for obstacles in the wheelchair's path. If an obstacle is detected, the wheelchair stops and performs collision avoidance. If no obstacle is present, the wheelchair moves according to joystick commands. The system continuously monitors user health parameters and emergency inputs. When an emergency button is pressed, the wheelchair stops and sends an alert; monitoring continues.

D. Hardware Components

- **ESP32 Microcontroller:** Central processing and wireless communication unit.
- **Ultrasonic Sensors:** Detect obstacles in front and sides of the wheelchair.
- **Motor Driver (L298N):** Controls direction and speed of wheelchair motors.
- **DC Motors:** Enable wheelchair movement.
- **Battery:** Supplies power to the system.
- **Emergency Switch:** Allows the user to send distress alerts manually.

E. Software and Communication

Programming is performed using Arduino IDE. ESP32 utilises built-in Wi-Fi for IoT communication. Data is transmitted to a cloud platform and mobile application for real-time monitoring and alerts [10], [14].

F. Working Principle

Ultrasonic sensors continuously monitor obstacles. ESP32 processes sensor data and controls motor movement to avoid collisions. In emergencies, alerts are sent to caregivers via an IoT platform. System data is logged for monitoring and analysis.

4. RESULTS AND DISCUSSION

The system was tested in indoor environments under controlled conditions.

Table 1 provides sample observations.

Parameter	Observed Value	Unit
Obstacle Detection Range	2 – 300	cm
Response Time	< 1	sec
Communication Delay	Low	—
Power Consumption	Moderate	—

Table 1: Experimental Observations

The system successfully avoided obstacles and transmitted alerts with minimal latency. Performance improvements align with recent smart wheelchair studies [3], [9], [12].

This developed system was compared with existing IoT-based systems, as shown in Table 1.

Table 2: Comparative Analysis Systems

Study	Parameters	Communication	Key Limitation / Notes
Kumar et al. [1]	Joystick + Ultrasonic	Bluetooth	Short range
Liu et al. [2]	Gesture + GPS	IoT	High complexity
Rahman et al. [3]	EEG-based Cloud	IoT	Signal noise
Cui et al. [4]	Sensor fusion	IoT	Outdoor dynamics
Proposed System	**Ultrasonic + IoT ESP32**	**Wi-Fi**	**Indoor focused**

5. CONCLUSION AND FUTURE WORK

This paper presented an IoT-based smart wheelchair system that enhances mobility, safety, and independence for users with physical disabilities. The system demonstrated reliable obstacle detection, real-time monitoring, and emergency alerting. Compared to existing systems, the proposed design offers lower cost, simplicity, and scalability [8], [11], [15].

Future work will focus on outdoor navigation enhancement, integration of machine learning for path planning, and health parameter monitoring, such as heart rate and fall detection.

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