

IoT Based Smart Wheelchair : An Assistive Innovation For Elderly And Physically Challengd Individuals

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Abstract- Smart wheelchairs are designed to significantly enhance the mobility, safety, and independence of physically disabled individuals by integrating modern technologies and intelligent control systems. These systems combine advanced communication technologies, smart sensors, and automated mechanisms to provide efficient and safe navigation in different environments. Obstacle detection is achieved using ultrasonic sensors, which continuously monitor the surroundings and help prevent collisions by alerting the system or stopping movement when necessary. Additionally, MPU sensors (such as MPU6050) are used to monitor tilt, orientation, and motion, ensuring stability and reducing the risk of accidents caused by imbalance or uneven surfaces. The wheelchair can be operated through a user-friendly joystick interface, allowing smooth manual control, while alternative control methods such as voice commands, and mobile application inputs provide flexibility and accessibility for users with varying abilities. At the core of the system, the ESP32 microcontroller processes sensor data in real time and controls the movement of the wheelchair efficiently. The integration of Firebase cloud technology enables data storage. Mobile application also includes AI-based voice feedback to inform users about movements such as forward, backward, left, and right, as well as warnings about detected obstacles. Overall, the system is designed to be user-friendly, energy-efficient, and adaptable to various environments including homes, hospitals, and outdoor areas. By promoting safety, autonomy, and inclusivity, the smart wheelchair contributes to improving the overall quality of life for differently-abled individuals.

Index Terms- Smart wheelchair, assisted mobility, artificial intelligence, computer vision, joystick control, voice command, mobile application control, obstacle detection, ESP32, voice recognition

I. INTRODUCTION

The worldwide population is gradually becoming old, and there are an increasing number of individuals who live with mobility-related disabilities. Though

the world has advanced in medicine, thereby prolonging lifespan, most aged people are faced with decreased physical power, neuropsychological complications, and locomotor problems. It has accordingly been shown that wheelchairs are immensely important in assisting such people to ensure that they remain independent and be able to carry out their day-to-day tasks. Basic mobility assistance with no advanced features, like adaptive control, obstacle detection, and hands-free operation, are mostly the only features of traditional wheelchairs. Such constraints may add to risks in safety and may often require constant support of caregivers particularly in indoor settings where there are barriers, narrow corridors and where there are areas of congestion. recent, artificial intelligence, embedded systems and low-power microcontrollers such as the esp32 have provided new opportunities to develop smart wheelchairs. the new generation of smart wheelchair systems combines several control systems such as joystick control, voice commands, wireless or mobile control, and mobility control. besides this, smart safety systems like obstacle detection, motion stabilization, and environment awareness also enhance general usability and safety of the system. This re-examines current technologies in smart wheelchair, with a thrust on control system, sensor integration and artificial intelligence-assisted capabilities. it also displays the existing research gaps and demonstrates the necessity of the cost-effective and efficient esp32-based smart wheelchair solutions capable of improving the mobility, safety, and autonomy of people with disabilities.

1.1 Literature Review

The development of smart wheelchair systems has evolved through several stages. Initially, control-based systems such as joystick-operated and basic

voice-controlled wheelchairs were introduced, enabling user movement but still requiring physical interaction, with voice commands being less effective in noisy environments. To enhance safety, sensor-based obstacle detection systems using ultrasonic sensors were implemented, allowing users to detect obstacles; however, these sensors were limited by short detection ranges, environmental sensitivity, and hardware complexity. More recent designs employ microcontroller-based smart controller systems, utilizing platforms like Arduino and ESP32, which offer low power consumption, wireless connectivity, and easy integration with sensors, motor drivers, and communication modules. The latest advancements focus on intelligent navigation and stability, incorporating AI-based navigation and IMU sensors, such as the MPU6050, to monitor inclination, vibration, and motion, thereby assisting in balance maintenance and minimizing the risk of accidents

1.2 Methodology

The development of the IoT-based Smart Wheelchair follows a structured methodology to ensure safe, intelligent, and user-friendly mobility for differently-abled individuals. The methodology involves several stages:

1. Requirement Analysis – Identifying the mobility challenges faced by wheelchair users, including obstacle avoidance, stability, and ease of control.
2. System Design – Designing the overall system architecture, integrating sensors, microcontrollers, motor drivers, and communication modules. Key modules include control systems, obstacle detection, intelligent navigation, and stability monitoring.
3. Hardware Implementation – Selecting and assembling hardware components such as ultrasonic sensors for obstacle detection, IMU sensors (e.g., MPU6050) for motion and balance tracking, and microcontrollers (Arduino/ESP32) for system control.
4. IOT Integration – Enabling wireless connectivity to monitor wheelchair status remotely and allowing real-time data transmission to a mobile for guardians or healthcare providers.

5. Control and Navigation – Implementing joystick or voice-based control along with mobile app control.
6. Testing and Evaluation – Conducting functional and performance testing to verify obstacle detection, motion stabilization, and responsiveness of control systems, ensuring safety and reliability.

The workflow begins when the user operates the wheelchair via joystick or voice commands. The system continuously monitors the environment using sensors, avoids obstacles using intelligent algorithms, maintains balance with IMU data, and provides feedback to the user or guardians through IoT connectivity.

1.3 Key Features

1. Multiple Control Options

Operable via joystick, voice commands and mobile app providing flexibility for users with different disabilities.

2. Obstacle Detection

Equipped with ultrasonic sensors to detect obstacles and prevent collisions, enhancing user safety.

3. Motion Stabilization

IMU sensors (e.g., MPU6050) monitor tilt, vibration, and movement to maintain balance and prevent accidents.

4. Low-Power and Efficient Design

Uses microcontrollers (Arduino/ESP32) to ensure low power consumption and efficient system operation.

5. Sensor Integration

Seamless integration with motors, motor drivers, and sensors for reliable and responsive performance.

6. Scalable Architecture

Modular design allows for future enhancements, such as GPS tracking, health monitoring, or automated route selection.

1.4 Technologies Employed

1. Flutter – Mobile application development
2. Dart – User Interface
3. Microcontroller –ESP32 for system control and processing.
4. Firebase – Data storage and connectivity.
5. Arduino IDE – For programming and uploading code to microcontrollers.
6. AI and ultrasonic sensors -- For intelligent navigation, obstacle avoidance, and for voice feedback to the user via mobile app.

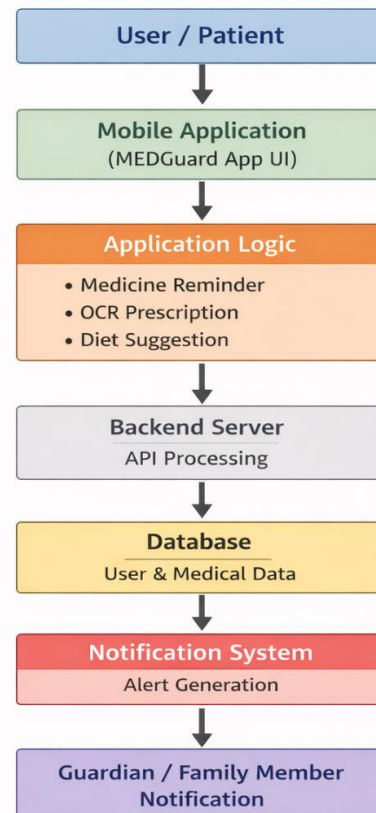
1.5 User Adoption and Impact

The IoT-based Smart Wheelchair is designed to ensure easy user adoption while creating a significant positive impact on users' lives. Its user-friendly features, such as joystick and voice control, along with automatic obstacle detection, make it simple for elderly individuals and people with physical disabilities to operate with minimal learning effort. The integration of IoT enables remote monitoring by caregivers and family members, increasing reliability and user confidence, while the system's flexible and scalable design allows customization for different environments like homes, hospitals, and rehabilitation centers. In terms of impact, the smart wheelchair enhances independence and mobility, allowing users to perform daily activities more comfortably and safely. Features like intelligent navigation and motion stabilization reduce the risk of accidents, while real-time alerts and monitoring provide added security and peace of mind. Overall, the system improves quality of life, promotes inclusive mobility, and reduces dependence on manual assistance.

1.6 Challenges and Limitations

- IoT features rely on stable internet, which may not be available in all areas.
- Ultrasonic sensors may be affected by environmental conditions and have a short detection range.
- Integration of multiple components (sensors, microcontrollers, IoT modules) increases design and maintenance complexity.
- Adding new features or upgrading the system may require redesign or additional resources.

1.7 Block Diagram



1.8 Conclusion

The IoT-based Smart Wheelchair system presents an innovative solution to enhance mobility, safety, and independence for individuals with physical disabilities. By integrating advanced technologies such as the ESP32 microcontroller, ultrasonic sensors for obstacle detection, MPU6050 for motion stability, and BTS7960 motor drivers for efficient movement control, the system ensures reliable and intelligent operation. The inclusion of multiple input methods, including joystick, voice commands, and mobile application control, makes the system user-friendly and accessible. Additionally, the AI-based voice feedback system improves user awareness by providing real-time updates on movement and obstacle detection. Overall, the proposed system demonstrates an effective combination of IoT, embedded systems, and intelligent control, contributing to safer navigation, reduced dependency on caregivers, and improved quality of life. Future enhancements can further expand its capabilities, making it more efficient, affordable, and widely

adoptable.

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