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Voice-Controlled Wheelchair Along with Health Monitoring

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Abstract

In recent years, mobility aids like wheelchairs have become essential for enhancing the independence of individuals with physical disabilities. However, traditional wheelchairs, often controlled manually or via joysticks, pose challenges for those with severe impairments. This project introduces a voice-controlled wheelchair integrated with health monitoring capabilities, addressing these limitations. The system features an ESP32 microcontroller that processes voice commands, such as "move forward" or "stop," captured by a microphone and converts them into precise motor actions. Safety is ensured through ultrasonic sensors that detect obstacles, while an emergency stop button provides instant control during critical moments. The wheelchair also incorporates health monitoring through sensors like a pulse oximeter, continuously tracking vital signs such as heart rate and oxygen saturation (SpO_2). These readings are displayed on a mobile app, enabling real-time health updates for both users and caregivers. The system's functionality has been rigorously tested, demonstrating high reliability in voice recognition, obstacle detection, and health data logging. By combining mobility, safety, and health tracking into a single device, this project significantly enhances the autonomy and well-being of users. It sets a benchmark in assistive technology by providing an accessible and comprehensive solution that addresses mobility and health needs simultaneously. The project's focus on seamless integration ensures a user-friendly experience, bridging the gap between mobility assistance and health monitoring. Moreover, the application of advanced microcontroller technology highlights the potential for further enhancements in assistive devices, paving the way for innovation in accessibility solutions.

Keywords*:* Physical disability, voice-controlled wheelchair, voice recognition, ultrasonic detection

INTRODUCTION

The wheelchair is a fundamental mobility device that empowers individuals with physical disabilities to navigate their surroundings independently. Traditional wheelchairs are generally divided into two types: self-propelled and assistive controlled. Self-propelled wheelchairs require users to exert manual effort through their hands and arms, while assistive-controlled models are operated using joysticks or similar devices. While effective, these traditional designs rely heavily on the user's muscular strength and motor dexterity, rendering them unsuitable for individuals with severe impairments in their upper extremities [1].

In response to these limitations, researchers have proposed various alternative control methods for wheelchairs. Some solutions include eye-gaze tracking, facial direction control, and bio-signal-based systems. Among these, voice control stands out as a particularly intuitive and accessible method, as it aligns with natural human communication

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patterns. Voice-controlled wheelchairs eliminate the need for physical interaction, making them ideal for individuals with significant motor disabilities [2–5].

Existing voice-controlled systems, however, often suffer from drawbacks. For example, many rely on internet-connected devices, such as smartphones or laptops, to process voice commands. These systems may experience delays due to connectivity issues or the requirement for simultaneous multi-modal inputs, complicating user interaction. Additionally, most lack integrated health monitoring features, which are critical for users with chronic health conditions. This project addresses these gaps by developing a voice-controlled wheelchair that integrates health monitoring and obstacle detection capabilities, providing a unified, user-friendly solution [6–11].

Voice control as a methodology in assistive technology not only empowers users but also ensures inclusivity by catering to those with severe physical limitations. By leveraging advancements in microcontroller technology and sensor integration, the proposed system bridges the gap between independence and safety for disabled individuals [12].

WHEELCHAIR CONTROLLING TECHNIQUES

Muscle Signal-Driven Wheelchair Control

Muscle signal-driven systems have been explored extensively in assistive technologies. Electromyography (EMG) signals are used to detect muscle activity, which is then translated into control commands for wheelchair navigation. This approach provides a hands-free solution for individuals unable to use traditional controls. However, these systems are often complex, requiring precise calibration and expensive equipment. They are also unsuitable for users with severely impaired muscle function, limiting their accessibility. For instance, users with progressive neuromuscular diseases might find EMG-based systems increasingly difficult to operate over time.

Despite their advantages, EMG systems often involve high costs and extensive maintenance requirements. Additionally, they rely on stable and uninterrupted muscle signals, making them less reliable for individuals with fluctuating or deteriorating muscle control. These factors underscore the need for simpler, more intuitive solutions like voice control, which can bypass such challenges.

Analysis of Health Monitoring in Assistive Wheelchair Technologies

Health monitoring systems are increasingly recognized as vital components of assistive devices. Continuous tracking of vital signs, such as heart rate and blood pressure, can provide early warnings of medical emergencies. Integrating these systems into wheelchairs enhances safety and autonomy for users, particularly those with chronic health conditions. However, standalone health monitoring devices often lack integration with mobility systems, making them less convenient for daily use. This disconnect necessitates the development of systems that unify mobility and health tracking into a single, seamless platform [3].

The integration of real-time health monitoring directly into mobility devices ensures continuous feedback and timely medical intervention. Furthermore, advancements in sensor accuracy and miniaturization have made it feasible to incorporate these features without compromising the portability or usability of the wheelchair.

Sensor-Based Autonomous Wheelchair with Obstacle Detection

Advancements in smart wheelchairs have focused on sensor-based navigation and obstacle detection. Systems incorporating ultrasonic, infrared, and global positioning system (GPS) sensors enable autonomous navigation, reducing the risk of collisions in complex environments. While effective, these systems primarily emphasize autonomous control, which may not suit users who prefer active engagement through voice commands or manual input. Additionally, sensor accuracy in detecting small or low-contrast obstacles can vary, necessitating regular calibration and updates to maintain system reliability [6].

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Obstacle detection using ultrasonic sensors has been a breakthrough in ensuring user safety. By providing real-time feedback, these sensors prevent potential accidents in crowded or dynamic environments. However, the integration of obstacle detection with voice control adds another layer of user convenience, allowing users to prioritize safe navigation without compromising control.

Survey of Internet of Things and Sensor-Based Health Monitoring

The integration of internet of things (IoT) has revolutionized health monitoring by enabling real-time data collection, remote tracking, and emergency alerts. Wearable sensors are commonly used to monitor vital signs such as oxygen saturation and heart rate. Applying this technology to wheelchairs can create a comprehensive health monitoring system, providing users and caregivers with critical health data on demand. IoT-based health monitoring also facilitates long-term health trend analysis, enabling proactive medical interventions.

IoT connectivity ensures that health data can be securely stored and accessed remotely, providing caregivers with the ability to monitor patients in real-time. This functionality is particularly valuable for elderly users or those living in remote areas where immediate medical assistance may not be readily available.

Survey of Voice Recognition and Speech-Controlled Systems

Advances in voice recognition technology have significantly improved the usability of assistive devices. Speech recognition systems now allow for hands-free control of wheelchairs, offering intuitive navigation options. These systems leverage natural language processing to interpret complex commands, enhancing user experience. However, integrating such systems with other essential features like health monitoring remains a challenge. Additionally, the accuracy of voice recognition can be affected by environmental noise, requiring robust noise-cancellation algorithms.

Voice-controlled systems represent an accessible alternative to traditional control mechanisms, especially for individuals with severe physical impairments. As voice recognition technology continues to evolve, it promises to overcome current challenges related to noise interference and command precision.

Survey of Joystick-Controlled Electric Wheelchairs

Joystick-controlled electric wheelchairs remain a popular choice for individuals with sufficient upper-body mobility. While these systems are reliable and easy to operate, they are unsuitable for users with severe physical limitations. Furthermore, they generally lack health monitoring features, necessitating separate devices for tracking vital signs. These limitations highlight the need for more advanced systems that combine intuitive control mechanisms with integrated health monitoring.

The simplicity of joystick-controlled systems has ensured their continued relevance; however, their inability to cater to a broader range of disabilities limits their scope. Integrating voice and sensor technologies can overcome these limitations while retaining the reliability of joystick systems.

PROPOSED METHODOLOGY

The development of the voice-controlled wheelchair (Figure 1) with health monitoring involves a well-defined methodology that integrates hardware selection**,** system design, and the integration of key components to create a functional, efficient, and user-friendly assistive device.

System Design

The voice-controlled wheelchair integrates multiple modules to ensure seamless functionality:

1. *Voice recognition system:* A microphone captures user commands, which are processed by the *VOSK speech recognition library.* The recognized commands are converted into control signals for the ESP32 microcontroller.
2. *Navigation and safety:* Ultrasonic sensors positioned at the front and rear detect obstacles, ensuring collision-free movement.

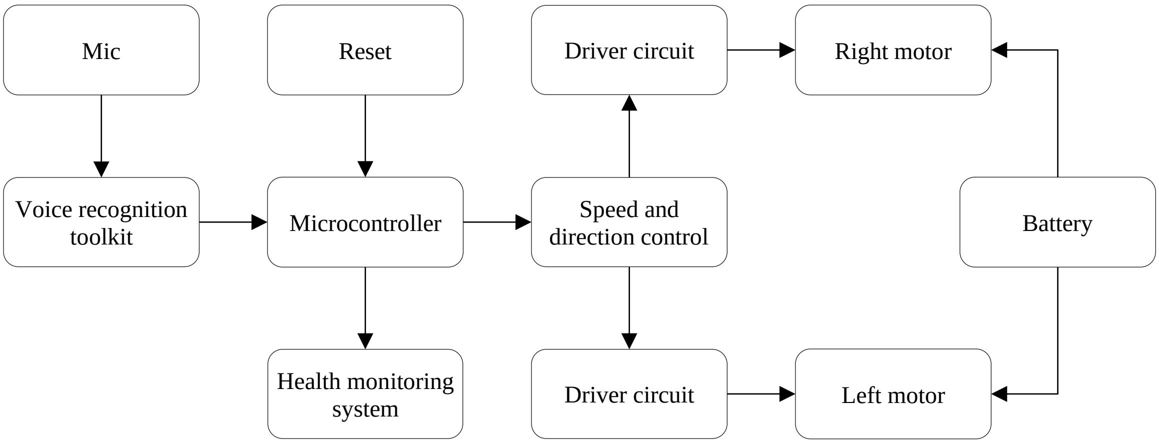

Figure 1. Block diagram of voice-controlled wheelchair.

3. *Health monitoring:* Sensors such as pulse oximeters measure parameters like heart rate and SpO_2. This data is transmitted to a mobile app using the ESP32's connectivity options.
4. *Control system:* The ESP32 microcontroller acts as the central unit, coordinating motor operations through a motor driver module based on voice inputs and sensor feedback.

Component Selection

- *ESP32 Microcontroller:* Selected for its dual-core processing capabilities, built-in Wi-Fi and Bluetooth, and energy efficiency. It serves as the system's primary processing unit.
- *Ultrasonic sensors:* Used for real-time obstacle detection, capable of identifying objects up to 4 meters (13 feet) away.
- *DC motors and motor driver module:* Responsible for driving the rear wheels and facilitating bidirectional movement with adjustable speed.
- *Health monitoring sensors:* Pulse oximeters and heart rate sensors ensure continuous tracking of vital signs.

System Integration

The system is programmed using the Arduino IDE, enabling efficient communication between components. Voice commands and sensor data are processed in real time to control motor movements and ensure accurate health monitoring. The entire system is powered by a rechargeable battery, offering portability and extended use. Data from the health sensors is seamlessly uploaded to the mobile app, ensuring accessibility for caregivers.

Applications of the System

- *Mobility assistance:* Empowers individuals with severe disabilities to navigate independently.
- *Safety enhancement:* Ultrasonic sensors prevent collisions, ensuring safe operation in crowded spaces.
- *Health monitoring:* Provides continuous tracking of vital signs, with real-time updates accessible through a mobile app.
- *Rehabilitation support:* Assists users undergoing physical therapy by providing data on mobility and health trends over time.

APPLICATIONS AND FUTURE ENHANCEMENTS

The "Voice-Controlled Wheelchair Along with Health Monitoring" project has wide-ranging applications that extend beyond basic mobility assistance. By combining advanced sensor technology with real-time health monitoring, this project provides solutions to several critical challenges faced by individuals with disabilities. Given below are its primary applications and potential avenues for enhancement.

Primary Applications

1. *Independent living for disabled individuals:* By offering a voice-controlled interface, this wheelchair enables users to move autonomously, eliminating dependency on caregivers for routine tasks like navigating through their homes or workplaces.
2. *Emergency health monitoring:* The integration of pulse oximeters and heart rate monitors ensures that caregivers can be alerted during health emergencies, allowing for timely medical interventions.
3. *Safe navigation in complex environments:* The use of ultrasonic sensors enhances safety by detecting obstacles, making the wheelchair suitable for both indoor and outdoor use.
4. *Remote monitoring:* Caregivers or healthcare providers can access real-time health data through a mobile app, making this system particularly valuable in-home healthcare settings.

Future Enhancements

1. *Additional health metrics:* Incorporating sensors to monitor body temperature, respiratory rate, and blood pressure could provide a more comprehensive health profile for users.
2. *Artificial intelligence-driven voice recognition:* Integrating artificial intelligence can enhance the accuracy and responsiveness of voice commands, even in noisy environments.
3. *GPS integration:* Adding GPS modules could allow users to navigate to specific destinations with minimal effort while enabling caregivers to track their location for added safety.
4. *Energy efficiency:* Future iterations can focus on optimizing battery usage to extend the wheelchair's operational hours.

CONCLUSION

The "Voice-Controlled Wheelchair Along with Health Monitoring" project presents a comprehensive solution to the challenges faced by individuals with physical disabilities. By integrating voice recognition, health monitoring, and obstacle detection into a single system, this wheelchair enhances both mobility and safety. The ESP32 microcontroller ensures seamless operation, enabling users to navigate their environment effortlessly through voice commands. Continuous health tracking provides critical data for users and caregivers, ensuring timely medical interventions when necessary.

This project not only demonstrates the potential of assistive technologies to improve the quality of life for disabled individuals but also highlights the need for future innovations. By addressing critical gaps in mobility and healthcare, this system sets a benchmark for accessibility solutions. Future enhancements, such as expanded health monitoring features and artificial intelligence-driven navigation, can further refine its utility and adaptability in real-world scenarios.

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