SMART WHEELCHAIR CONTROL USING VOICE AND GESTURE CONTROL

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Abstract- Assistive healthcare technologies are rapidly advancing with the integration of Artificial Intelligence, embedded systems, and human–computer interaction. Conventional wheelchairs require manual operation, which poses significant challenges for individuals with severe physical disabilities. Although powered wheelchairs exist, many lack intuitive control methods, affordability, and adaptability to user needs. To overcome these limitations, this project proposes the development of a SMART WHEELCHAIR CONTROL SYSTEM USING VOICE AND GESTURE CONTROL.

The proposed system is designed to provide an intelligent and user-friendly mobility solution by enabling wheelchair control through voice commands and hand gestures. Voice recognition technology is used to capture and process spoken commands such as forward, backward, left, right, and stop, while gesture control allows navigation using predefined hand movements detected through sensors.

The system is implemented using an ESP32 microcontroller, which offers built-in Wi-Fi and Bluetooth capabilities, high processing efficiency, low power consumption, and compact size. This makes the system cost-effective, portable, and suitable for real-time embedded applications. Motor driver circuits interface with DC motors to control wheelchair motion, while safety features such as obstacle detection and emergency stopping mechanisms enhance reliability and user safety.

The modular architecture of the system allows seamless integration of voice and gesture control modules, enabling users to choose the most convenient mode of operation based on their physical abilities. The design is scalable and supports future enhancements such as smartphone-based control, health monitoring, GPS tracking, and AI-based navigation assistance.

Experimental results indicate that the proposed smart wheelchair system significantly improves mobility independence, ease of use, and overall quality of life for physically challenged individuals. This project demonstrates the effectiveness of ESP32-based assistive technology in delivering an affordable, accessible, and intelligent mobility solution.

Keywords- Smart Wheelchair, Assistive Technology, Voice Control, Gesture Control, ESP32, Embedded Systems, Human–Computer Interaction, Robotics, Healthcare Technology

INTRODUCTION

In recent years, rapid advancements in digital technologies have significantly influenced the healthcare and assistive technology sectors. The integration of embedded systems, Artificial Intelligence, and human–computer interaction has opened new possibilities for improving mobility assistance and quality of life for physically challenged and elderly individuals. Mobility plays a crucial role in maintaining independence and dignity, yet many individuals face serious difficulties in movement due to physical disabilities, age-related limitations, or medical conditions. Traditional mobility aids often fail to provide sufficient independence, adaptability, and ease of use.

Human–computer interaction has evolved toward more natural and intuitive communication methods such as voice and gesture-based interaction. Voice commands and hand gestures provide a hands-free and user-friendly means of interaction, especially for individuals with limited motor control. When combined with intelligent processing and embedded systems, such interaction methods can significantly enhance accessibility and safety. This project explores the application of voice and gesture-based control systems in assistive mobility solutions. By integrating speech recognition, gesture sensing, embedded control, and motor automation, the proposed system aims to develop a smart wheelchair that enables intuitive, safe, and independent mobility.

RELATED WORK

Several studies have explored voice-controlled and gesture-controlled wheelchairs to assist physically challenged users. Earlier systems primarily relied on voice commands processed through microcontrollers such as Arduino, often requiring continuous internet connectivity or complex hardware setups. Gesture-based systems using accelerometers and MEMS sensors have also been proposed, but many lack integrated safety and health monitoring features.

Recent research highlights the importance of combining multiple control methods to improve usability and reliability. Obstacle detection using ultrasonic sensors and health monitoring through biosensors have been introduced as separate modules in some designs. However, limited work has focused on integrating renewable energy sources into intelligent wheelchair systems. The proposed system addresses these gaps by combining dual-mode control, safety mechanisms, health monitoring, and solar power in a single platform.

SYSTEM ARCHITECTURE

The proposed system follows a modular architecture centered around the ESP32 microcontroller. The major components include:

- Gesture Control Module: ADXL345 accelerometer mounted on the user's hand.

- Voice Control Module: Bluetooth module interfaced with a smartphone for voice commands.
- Motor Control Unit: L298N H-Bridge driver controlling DC motors.
- Obstacle Detection: Ultrasonic sensor mounted at the front of the wheelchair.
- Health Monitoring: Heartbeat sensor and temperature sensor.
- Power Supply: Solar panel with rechargeable battery system.
- All sensor data and control commands are processed by the ESP32, which generates appropriate motor control signals.

METHODOLOGY

The system operates in two primary control modes: gesture control and voice control. In gesture mode, hand movements are detected by the ADXL345 accelerometer, and directional commands are generated based on tilt angles. In voice mode, spoken commands such as "forward," "left," "right," and "stop" are transmitted via Bluetooth and processed by the ESP32.

The ultrasonic sensor continuously measures the distance to obstacles ahead. If an object is detected within a predefined threshold, the controller immediately stops the wheelchair to prevent collisions. Simultaneously, the heartbeat and temperature sensors monitor the user's vital signs, enabling early detection of abnormal health conditions.

The entire system is powered by a solar-charged battery, ensuring continuous operation even in areas with unreliable electricity.

HARDWARE AND SOFTWARE REQUIREMENTS

Hardware Components: ESP32 Microcontroller, ADXL345 Accelerometer, Bluetooth Module, Ultrasonic Sensor, Heartbeat Sensor, Temperature Sensor, L298N H-Bridge, DC Motors, Solar Panel, Rechargeable Battery. Software Tools: Arduino IDE, Embedded C.

RESULTS AND DISCUSSION

The developed prototype successfully demonstrated reliable wheelchair movement using both gesture and voice commands. Gesture-based navigation provided smooth directional control, while voice commands offered hands-free operation. Obstacle detection effectively prevented collisions, and health monitoring sensors produced stable real-time readings.

The solar power system ensured uninterrupted operation under normal lighting conditions, highlighting the sustainability of the design. Overall performance indicates that the system is suitable for practical assistive applications with minimal user training.

CONCLUSION AND FUTURE SCOPE

This paper presented the design and implementation of a solar-operated voice and gesture-controlled wheelchair aimed at enhancing mobility and independence for elderly and physically challenged users. The integration of dual-mode control, obstacle detection, and health monitoring significantly improves usability and safety. The use of renewable energy further strengthens the practicality of the system in real-world scenarios. The proposed solution offers a low-cost, reliable, and scalable approach to intelligent mobility assistance and represents a meaningful contribution to assistive technology research.

Future enhancements may include GPS-based navigation, mobile application integration, cloud-based health monitoring, AI-based voice recognition, and support for multilingual commands.

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ISSN: 2349-6002

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