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Arduino-Based Smart Wheelchair with Obstacle Detection and Joystick Control

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Abstract
Mobility assistance devices play a vital role in improving the quality of life for individuals with physical disabilities, paralysis, age-related limitations, or impaired motor functions. Conventional manual wheelchairs require significant physical effort, while commercially available smart or motorized wheelchairs are often expensive and inaccessible. This paper presents the design and development of a Smart Wheelchair using Arduino UNO, aimed at providing an affordable, safe, and user-friendly mobility solution. The proposed system integrates Arduino UNO, ultrasonic sensors, joystick control, and an L298N motor driver to enable intelligent navigation. The wheelchair responds to user input through a joystick and employs real-time obstacle detection to prevent collisions by automatically stopping or altering movement. The microcontroller processes sensor data and generates appropriate motor control signals, ensuring smooth and precise movement in forward, backward, and turning directions. The system is designed to be low-cost, modular, and easily scalable. Experimental testing confirms that the wheelchair successfully detects obstacles, provides stable movement, and enhances user safety.
Keywords— Smart Wheelchair, Arduino UNO, Obstacle Detection, L298N Motor Driver, Ultrasonic Sensor, Joystick Control, Assistive Technology, Embedded Systems, Mobility Aid.

I. INTRODUCTION

Mobility is one of the most fundamental human needs, essential for performing daily activities and maintaining social and emotional wellbeing. However, millions of people worldwide suffer from mobility impairments caused by spinal cord injuries, neurological disorders, limb amputations, stroke, muscular dystrophy, and age-related physical limitations. For such individuals, wheelchairs play a vital role in restoring independence, accessibility, and personal dignity.

Traditional manual wheelchairs, although affordable, require significant upper-body strength which many patients — especially quadriplegics, paralytics, or elderly individuals — do not possess. While powered electric wheelchairs exist, they are extremely expensive and technologically complex, making them inaccessible for middle- and lower-income groups.

With advancements in embedded systems, microcontrollers, and low-cost sensors, Arduino-based smart wheelchairs have emerged as a practical and affordable solution. They provide autonomous control, obstacle detection, user-friendly navigation, and improved safety at a fraction of the cost of commercial smart wheelchairs. This paper presents an Arduino UNO based Smart Wheelchair that addresses these mobility challenges through an integrated embedded system approach.

II. PROBLEM STATEMENT

People with physical disabilities face several critical challenges related to mobility, independence, and safety. The major problems identified are:

- Manual wheelchairs require significant physical effort, rendering them unusable for many disability types such as paralysis and quadriplegia.
- Commercial electric wheelchairs are prohibitively expensive and technologically complex for most patients.
- Lack of real-time obstacle detection in low-cost mobility devices leads to collisions and safety risks.
- Absence of automated navigation assistance forces dependency on caregivers.
- High cost of existing smart wheelchair solutions makes them inaccessible to lower-income groups.

Due to these issues, there is a clear requirement for a cost-effective and intelligent wheelchair system capable of obstacle avoidance, automated motion control, and safe indoor navigation.

III. PROPOSED SYSTEM

The proposed system is a Smart Wheelchair developed using Arduino UNO microcontroller technology. The system provides joystick-based directional control combined with automated real-time obstacle detection using an ultrasonic sensor. The Arduino UNO acts as the central processing unit, reading joystick analog inputs and ultrasonic sensor data, and generating appropriate motor control signals through an L298N dual H-bridge motor driver.

The wheelchair supports forward, backward, left turn, and right turn movements controlled via a two-axis analog joystick. The HC-SR04 ultrasonic sensor continuously measures the distance to obstacles ahead. When an obstacle is detected within the defined safety threshold (20 cm), the system automatically overrides joystick commands and halts the motors to prevent collision.

The proposed system improves assistive mobility by combining user-controlled navigation with automated safety features into a single low-cost integrated platform suitable for indoor environments.

IV. SYSTEM ARCHITECTURE

The proposed Smart Wheelchair system consists of distinct functional units that work together for motion control and obstacle avoidance.

A. User Input Module

The user input module comprises an analog joystick that provides two-axis directional commands (X and Y axes). The Arduino reads analog voltages from the joystick through pins A0 and A1. A dead-zone filter is applied to prevent unintended motion from small joystick deviations near center.

B. Sensing Module

The sensing module uses an HC-SR04 ultrasonic sensor for real-time front obstacle detection. The sensor operates using an echo-trigger mechanism and measures distances by calculating the time taken for ultrasonic pulses to reflect back. It covers a range of 2 cm to 400 cm with approximately ±3 mm accuracy.

C. Processing Unit

The processing unit consists of the Arduino UNO microcontroller (ATmega328P, 16 MHz), which reads sensor and joystick data, executes control logic, and sends motor commands. It features 14 digital I/O pins and 6 analog input pins.

D. Actuation / Motor Control Unit

The actuation unit includes an L298N dual H-bridge motor driver connected to two DC geared motors. The driver supports independent control of both motors for differential drive, enabling direction and speed control via PWM signals on ENA/ENB pins.

E. Power Module

A 12V rechargeable battery powers the DC motors and supplies regulated 5V to the Arduino and peripheral sensors through the L298N onboard regulator.

V. HARDWARE REQUIREMENTS

Component	Function / Purpose
Arduino UNO Microcontroller	*Central processing unit and motor control*
L298N Motor Driver Module	*Controls two DC geared motors via H-bridge*
HC-SR04 Ultrasonic Sensor	*Detects obstacles and measures distance*
Analog Joystick Module	*User input for directional control*
DC Geared Motors (×2)	*Provides wheel drive for movement*
12V Rechargeable Battery	*Provides electrical power to the system*
Wheelchair Chassis / Frame	*Structural body for mounting components*
Wheels and Castor Wheel	*Enables steering and directional mobility*
Connecting Wires and Breadboard	*Signal and power routing for prototyping*

TABLE I. Hardware Components Used

VI. SOFTWARE REQUIREMENTS

The software tools required for the implementation are:
Arduino IDE for programming the Arduino UNO microcontroller.
Embedded C / Arduino programming language.
Serial Monitor (within Arduino IDE) for debugging and sensor-data visualization.
Circuit Simulation Software (Proteus / Tinkercad) for pre-testing circuit designs.

VII. WORKING METHODOLOGY

The working process of the proposed system is explained as follows:

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The system is powered ON and Arduino UNO is initialized along with all peripherals.
The joystick module and ultrasonic sensor are continuously polled in the main loop.
The ultrasonic sensor fires a trigger pulse and measures the echo return time to compute distance.
If the measured distance is less than the safety threshold (20 cm), the system immediately stops the motors regardless of joystick input.
If no obstacle is detected, joystick analog values (0-1023) are read on A0 (X-axis) and A1 (Y-axis).
A dead-zone filter suppresses joystick drift near the center position to prevent unintended movement.
Joystick values are mapped to motor control commands: forward, backward, left turn, or right turn.
Motor speed is controlled via PWM signals (analogWrite) on ENA and ENB pins of the L298N driver.
Differential drive logic independently controls left and right motors for turning maneuvers.
The process repeats continuously for real-time navigation and safety monitoring.

VIII. ALGORITHM

Start the system.
Initialize Arduino UNO, HC-SR04 ultrasonic sensor, joystick module, L298N motor driver, and DC motors.
Trigger ultrasonic sensor and compute distance from echo pulse width.
If distance < stopDistance (20 cm), execute stopMotors() and return.
Read joystick X-axis value (A0) and Y-axis value (A1).
Apply dead-zone filter to joystick readings.
If Y > 600, call moveForward().
Else if Y < 400, call moveBackward().
Else if X > 600, call turnRight().
Else if X < 400, call turnLeft().
Else call stopMotors().
Repeat the process continuously.

IX. RESULTS AND DISCUSSION

The proposed Arduino UNO based Smart Wheelchair was implemented and tested successfully under different environmental conditions. During testing, the system demonstrated reliable joystick-based directional control, allowing smooth forward, backward, left-turn, and right-turn movements.

The HC-SR04 ultrasonic sensor accurately detected obstacles in the path of the wheelchair and triggered immediate motor stop within less than 100 ms response time. This confirmed reliable collision prevention in indoor environments. The L298N motor driver responded promptly to Arduino PWM signals and provided stable motor speed and direction control throughout the testing process.

The joystick dead-zone filter effectively eliminated unwanted drift and unintended motion near the neutral joystick position. The overall system demonstrated low power consumption, stable performance, and efficient operation suitable for assistive mobility applications.

X. ADVANTAGES OF PROPOSED SYSTEM

The major advantages of the proposed system are:

Provides enhanced mobility and independence to users with physical disabilities.

Real-time obstacle detection improves safety by preventing collisions in indoor environments.

Low-cost implementation using readily available components makes it more affordable than commercial motorized wheelchairs.

Joystick-based control is simple, user-friendly, and suitable even for users with limited hand strength.

Modular design allows easy maintenance and supports upgrades such as Bluetooth or voice control.

Differential drive mechanism enables smooth and precise turning maneuvers.

Scalable architecture supports future integration of IoT monitoring, GPS tracking, and AI-based navigation.

XI. APPLICATIONS

The proposed system can be applied in:

1. Hospitals, rehabilitation centers, and old-age homes for safe patient mobility.
2. Home environments to assist elderly or differently-abled users in daily mobility tasks.
3. Care facilities to reduce physical strain on caregivers.
4. Educational and research prototyping for assistive robotics and embedded systems.
5. Indoor navigation assistance for individuals with paralysis, spinal cord injuries, or muscle weakness.

XII. CONCLUSION

This paper presented a Smart Wheelchair system developed using Arduino UNO microcontroller and embedded system technology. The proposed system enables users to navigate safely using joystick-based directional control while the integrated ultrasonic sensor provides automated real-time obstacle detection to prevent collisions. The system also incorporates differential drive control for smooth and precise turning.

The developed system improves mobility, independence, and safety for differently-abled individuals while maintaining low implementation cost. Real-time obstacle avoidance and intuitive joystick control make the system suitable for modern assistive mobility applications. The results indicate that the proposed system is reliable, efficient, scalable, and effective as a foundation for advanced smart wheelchair development.

XIII. FUTURE SCOPE

The proposed system can be enhanced further by:

Integrating voice-controlled navigation using speech recognition for hands-free operation.

Adding Bluetooth or Wi-Fi connectivity for remote monitoring and assistance via mobile application.

Implementing AI-based autonomous navigation using multiple sensors or computer vision.

Incorporating IoT features such as health monitoring (heart rate, temperature) and cloud connectivity.
Using more powerful motors and all-terrain wheels to support outdoor mobility and higher load capacity.
Adding GPS tracking and emergency alert system for safety during unexpected situations.
Integrating multi-directional obstacle detection using additional ultrasonic or infrared sensors.

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