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Gesture-Controlled Automated Wheelchair Using Arduino

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Abstract: *In recent years, assistive technologies have evolved to empower individuals with mobility impairments by offering smart, user-friendly alternatives to traditional mobility aids. This project presents the design and development of a gesture- controlled automated wheelchair using Arduino and flex sensors. The system allows users to control wheelchair movement through intuitive finger gestures, captured via a wearable glove embedded with sensors. These gestures are interpreted by an Arduino microcontroller and translated into directional commands— forward, backward, left, right, or stop—enabling seamless navigation without the need for physical exertion or joystick handling.*

Key words: *Gesture recognition, Arduino, Flex sensors, Assistive technology, Automated wheelchair, Human–computer interaction, Motor control, Mobility aid.*

I.INTRODUCTION

The integration of embedded systems and human–computer interaction into assistive technologies has opened new avenues for enhancing mobility among individuals with physical impairments. Conventional wheelchair systems— manual or joystick-controlled—are often inaccessible to users with limited upper limb mobility. This limitation inspired the development of a gesture-controlled automated wheelchair, which enables intuitive navigation using simple finger movements. The proposed system utilizes flex sensors embedded in a glove to capture hand gestures, which are interpreted by an Arduino microcontroller to drive the wheelchair in various directions such as forward, backward, left, and right [1].

Existing solutions like joystick-based electric wheelchairs, voice-controlled systems, and brain-computer interface (BCI)-based methods either lack intuitiveness or are prohibitively expensive and complex for real-world deployment [2]. The system presented in this work provides a cost-effective and user-friendly alternative by focusing on users who retain finger mobility but experience difficulty with more extensive hand or arm movement.

Future scopes are:

- Integration of ultrasonic or infrared sensors for real- time obstacle detection and automatic avoidance, improving overall safety.
- Implementation of voice control features as an alternative for users who cannot perform hand gestures.
- Addition of Bluetooth or Wi-Fi modules to enable wireless communication and control through smartphones or companion devices.
- Inclusion of GPS tracking and navigation for outdoor mobility and location-based assistance during emergencies.
- Development of a smart battery management system for efficient charging, usage monitoring, and extended operational time.
- Introduction of an automatic braking system to prevent unintended motion due to unrecognized or unsafe gestures.
- Expansion into smart home integration, allowing control of lights, fans, and doors using the same gesture interface.

II.LITERATURE SURVEY

This literature survey offers a comprehensive overview of existing efforts and technologies related to gesture-controlled mobility aids, with a focus on wheelchairs. The aim is to analyze current methodologies, identify their limitations, and understand the scope for innovation in the domain of assistive mobility.

A. Flex Sensor and Arduino-Based Wheelchair Control, Smith et al., 2018

This study used flex sensors integrated with an Arduino microcontroller to control a wheelchair via hand gestures. While it provided a basic gesture recognition model, its functionality was mainly restricted to indoor environments, limiting its practical usability in diverse conditions.

B. Accelerometer-Based Hand Gesture Detection, Kumar et al., 2019

In this work, accelerometers were used to detect hand tilt and orientation for controlling wheelchair movement. The system showed promise but lacked obstacle detection capabilities, which is essential for ensuring user safety in real-world applications.

C. Wireless Glove with Bluetooth Module, Lee et al., 2020

This project focused on building a wireless glove using a Bluetooth module to send gesture data to the wheelchair. Although it provided mobility without physical wires, the cost of components and complexity of the wireless setup made it less viable for cost-sensitive users.

D. Gesture and Voice-Controlled Hybrid Wheelchair, Roy et al., 2021

A hybrid system combining both gesture and voice commands was proposed. While the concept provided redundancy and flexibility in control, the integration of multiple systems made the overall setup complex and less user-friendly for people with cognitive or speech impairments.

E. MEMS Sensor-Based Directional Control, Sharma et al., 2020

This paper explored the use of MEMS sensors to determine hand gestures. Though the sensors were efficient in detecting motion, the system showed instability when used on uneven or rough terrains, which poses safety concerns in real-world mobility situations.

III.IMPLEMENTATION

A. Methodology

The gesture-controlled wheelchair is built using a glove equipped with flex sensors, which detect finger movements and send signals to an Arduino Uno. These analog signals are processed and converted into digital commands that control the direction of the wheelchair—such as forward, backward, left, right, or stop.

Each gesture corresponds to a specific motion. For instance, slightly bending all fingers moves the wheelchair forward, while keeping all fingers straight stops it. These commands are sent to an L298N motor driver, which powers the DC motors connected to the wheelchair.

This entire process is powered by a 12V rechargeable battery, making the system portable and energy-efficient. The setup was first tested on a breadboard and then integrated into a working prototype.

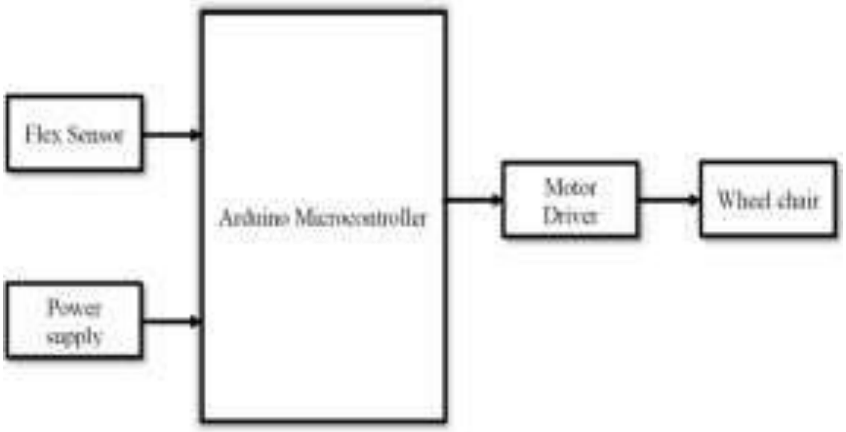


Fig 1 Block diagram of the gesture-controlled wheelchair system

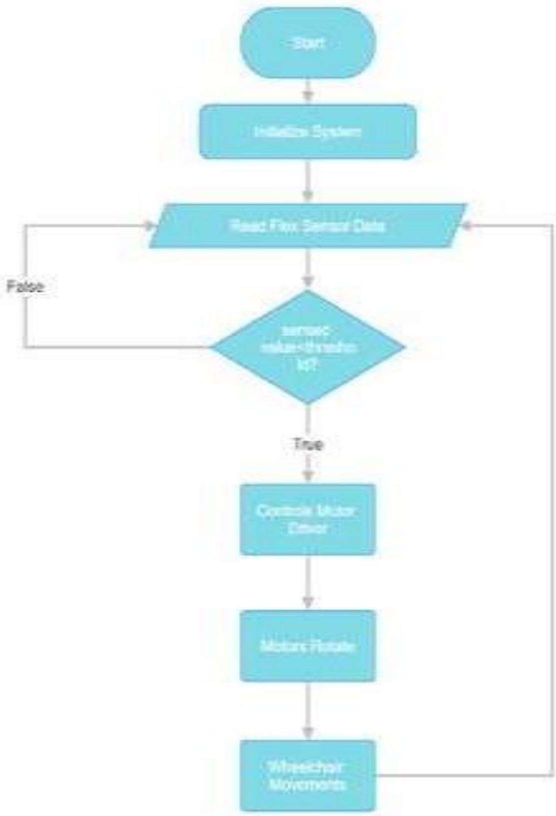
A block diagram (Fig 1) illustrates the overall architecture:

- **Flex Sensors:** These are mounted on a glove worn by the user. As the user bends or straightens their fingers, the resistance of each sensor changes. This variation is sent as an analog signal.
- **Arduino Microcontroller:** This acts as the processing unit. It takes in signals from the flex sensors, interprets them based on pre-defined thresholds, and translates them into movement commands. It also receives power from the power supply.
- **Power Supply:** A 12V rechargeable battery powers the Arduino and other components, making the entire setup wireless and portable.
- **Motor Driver (L298N):** The commands from the Arduino are sent to the motor driver, which then controls the speed and direction of the DC motors.
- **Wheelchair Movement:** Finally, based on the interpreted gesture, the motor driver moves the wheelchair forward, backward, or turns it left or right.

This modular approach ensures that each component works seamlessly, offering users a smooth and intuitive control experience.

B.Flow chart

This section outlines the logical flow of the gesture- controlled wheelchair system, from capturing user gestures to executing wheelchair movements.



[1] Glove Input

The user wears a glove embedded with flex sensors. When fingers are bent or straightened, these sensors detect the movement by measuring resistance changes. This is the starting point for capturing gesture-based control.

[2] Gesture Recognition

The bending of fingers results in analog voltage signals. These values are continuously read by the Arduino. Each unique combination of finger positions is mapped to a specific movement (e.g., forward, left, stop).

[3] Signal Processing (Arduino)

The Arduino Uno converts the analog signals from the sensors into digital commands. These commands correspond to actions like move forward, turn left, turn right, go backward, or stop.

[4] Motor Control (Motor Driver)

The Arduino sends these movement commands to the L298N motor driver, which controls the speed and direction of the DC motors connected to the wheelchair.

[5] Motion Execution (Wheelchair Movement)

Based on the motor driver output, the wheelchair responds to the recognized gesture by moving in the intended direction. Each gesture results in a precise and reliable motion.

[6] System Feedback & Adjustment

During testing, sensor readings and responses are monitored using the serial monitor in the Arduino IDE. This helps in calibrating the flex sensors and adjusting thresholds for more accurate gesture detection.

C. Hardware Requirements:

The hardware implementation of this project is essential to achieve real-time gesture recognition and reliable wheelchair control. The components used are cost-effective, readily available, and suitable for embedded system development. The following hardware was utilized:

[1] Arduino Uno (ATmega328P)

Acts as the core processing unit of the system. It receives analog signals from the flex sensors, processes them, and sends corresponding digital commands to the motor driver.

[2] Flex Sensors

These are resistance-based sensors attached to a wearable glove. They detect finger bending by changing resistance, providing gesture input to the Arduino.

[3] L298N Motor Driver

A dual H-bridge motor driver used to control the direction and speed of the DC motors. It acts as an interface between the Arduino and the motors.

[4] DC Motors (12V geared)

These motors power the movement of the wheelchair. Their direction and speed are controlled based on the user's hand gestures.

[5] Rechargeable Battery (12V)

Provides power to the entire system, including the Arduino, motor driver, and motors. It ensures portability and consistent operation.

[6] Jumper Wires and Breadboard

Used for wiring connections and initial circuit prototyping. They allow easy testing and modification of the system before final integration.

This combination of components enables a simple, responsive, and low-cost solution for gesture-based wheelchair control.

D. Software Requirements

This project is developed and tested in a real-time embedded environment using widely accessible software tools. The selected platforms ensure efficient coding, debugging, and reliable gesture-to-motion translation. Below are the essential software tools used for implementation:

[1] Arduino IDE

The primary programming environment used for writing, uploading, and testing code on the Arduino Uno. It provides an easy-to-use interface and supports serial communication, which is vital for monitoring sensor data during development.

[2] Serial Monitor (Arduino Tool)

Used for real-time debugging and analysis of sensor values. It helps in calibrating the flex sensors by displaying the raw analog input, allowing fine-tuning of gesture detection thresholds.

[3] Embedded C/C++ (Arduino Language)

The logic for reading sensor values, mapping gestures, and controlling motors is written in embedded C/C++. This language offers flexibility and direct hardware control, which is essential for smooth and responsive system performance.

E. Applications

- Useful for individuals with limited mobility.
- Applicable in hospitals and rehabilitation centers.
- Ideal for elderly care and assisted living.
- Can be extended for smart home integration.
- Suitable for educational and research purposes.
- Helps users during temporary disabilities or recovery phases.

F. Advantages

- Enables hands-free wheelchair control using simple finger gestures.
- Easy to operate and user-friendly, even for first-time users.
- Cost-effective and built with easily available components.
- Lightweight and portable design suitable for daily use.
- Modular and scalable for adding features like obstacle detection or voice control.
- Enhances user independence and quality of life.

IV. RESULTS

The gesture-controlled wheelchair system was tested under indoor conditions to evaluate its performance and responsiveness. The results demonstrated that the system accurately interpreted finger gestures and executed the corresponding wheelchair movements with minimal delay.

Each gesture was mapped to a specific motion command. During testing, the system responded consistently and reliably. The average response time between the user performing a gesture and the wheelchair moving was less than 500 milliseconds. Gesture recognition accuracy was observed to be between 90% to 95% under stable hand conditions.

The table below shows the gesture mapping used in the system:

Table 1 Gesture recognition Performance

Gesture	Finger Movement	Wheelchair Action
Forward	All fingers bent slightly	Moves forward
Backward	Index and middle finger bent	Moves backward
Left	Only index finger bent	Turns left
Right	Only middle finger bent	Turns right
Stop	All fingers straight	Stops

The prototype responded correctly to all defined gestures:

- When all fingers were slightly bent, the wheelchair moved forward.
- When index and middle fingers were bent, it moved backward.
- When only the index finger was bent, it turned left.
- When only the middle finger was bent, it turned right.
- When all fingers were straight, the wheelchair stopped.

These results confirm that the system is suitable for users with limited mobility and can effectively enhance their independence in controlled environments.

V. CONCLUSION

The Gesture-Controlled Automated Wheelchair project was designed and implemented with the goal of assisting physically disabled individuals in achieving mobility with ease and independence. By using finger gestures detected through flex sensors, the user is able to control the direction and movement of the wheelchair. The system was successfully built and tested using Arduino Uno, motor drivers, and a wheelchair chassis.

The final prototype proved to be a cost-effective and practical solution that can be easily deployed in real-life scenarios.

This system offers a user-friendly experience and successfully addresses the primary issues of conventional manual or joystick-controlled wheelchairs. It also serves as an innovative application of embedded systems and human- computer interaction

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