

Design & Development of Mobility Vehicle for Paralyzed Patients

Pratham Raybole¹, Harshit Singh¹, Ketan Patil¹, Ketan Sonawane¹, Dr. S J Navale²

¹ Student, Department of Mechanical Engineering, AISSMS College of Engineering, Pune, India

² Assistant Professor, Department of Mechanical Engineering, AISSMS College of Engineering, Pune, India

Abstract - This head motion-controlled wheelchair was designed to counter the challenges of people with quadriplegia or tetraplegia who are dependent on wheelchairs. One of the gravest challenges for quadriplegics is the immobility without help. As a consequence of impaired function of the arm, quadriplegics cannot use conventional wheelchairs or traditional powered wheelchairs. The main goal of this head motion-controlled wheelchair is to resolve and improve problems connected with the independent movement of individuals confined to wheelchairs. This ground vehicle on wheels is designed specifically for high torque and low-speed operation. This makes it easy for it to transit upward on ramps and inclines. This design uses an accelerometer-equipped helmet, which it operates from.

Key Words: *Quadriplegia, paralysis, head motion-controlled wheelchair, autonomous mobility, motor mechanism, high torque, accelerometer-equipped helmet*

1. INTRODUCTION

Mobility is a key ingredient of autonomous human existence and has a significant impact on the general quality of life. Mobility loss in individuals with severe physical impairment, especially those with quadriplegia, not only results in physical impairment but also psychological disability in terms of decreased self-esteem and reliance on others for everyday toileting. Quadriplegia or paralysis of four limbs is often caused due to spinal cord injury but may result from disease as well, i.e., due to stroke, arthritis, or degenerative illnesses. According to worldwide data, about 43 million people have a disability, and more than 3.3 million are solely dependent on wheelchairs for their mobility needs. Nonetheless, standard electric wheelchairs are generally meant for patients who have upper body control, making them useless for quadriplegic patients. This study responds to the serious need for a substitute wheelchair control interface that allows independent mobility for users who cannot operate traditional joystick-controlled systems. Head motion presents a viable alternative, since the majority of quadriplegic patients have the residual motor function to move their heads. Utilizing this ability, a head orientation-controlled system can deliver a functional and user-friendly means of navigation. The system proposed combines aspects of rehabilitation engineering to create a

human-machine interface that senses head movements and converts them into direction commands—forward, backwards, left, and right—to drive a powered wheelchair. By bringing together sensors, microcontrollers, and signal processing elements, the system seeks to identify and respond to user intent with high accuracy and in real-time. While increasing mobility, this also allows the user to achieve autonomy, take part in social activity and contribute to well-being as a whole. Here we present the design and implementation of a head movement-controlled wheelchair system, providing an affordable mobility option for quadriplegic users. The system is a step up from current wheelchairs and falls in line with the general mission of inclusive design and rehabilitation engineering.

1.1 PROBLEM STATEMENT

Individuals with very limited physical capacities, such as quadriplegia or paralysis, must utilize a wheelchair controlled by head movement. This new technology increases the mobility and independence of users by enabling them to use the wheelchair through simple head movement. Unlike usual joystick-powered wheelchairs, this approach allows users to maneuver more easily and precisely using a more natural yardstick of movement. Individuals with very limited limb function capabilities can more easily engage with the world around them through head motion control, which provides a sense of independence and dignity. As it turns out, this technology not only promotes inclusiveness but also makes people's lives as a whole more civilized for those who suffer from a severe mobility problem.

1.2 METHODOLOGY

This study tackles a fully paralyzed wheelchair by designing a vehicle head-control system for people with paralysis. This process is divided into five stages: integrating the sensors, processing the signals, categorizing with machine learning, implementing safety systems and evaluating users.

1. Integration of peripherals: The head position is captured using an Inertial Measurement Unit (IMU)(MPU6050), which has a 3-axis accelerometer and a gyroscope. The data is collected through an Arduino Uno microcontroller, which can sample at a frequency of 50Hz.

2. Processing the information: A Kalman filter removes the IMU data stream motion errors (drift) and improves accuracy. The head's dynamic position estimation is pose-dependent.

3. Motion Recognition Through Neural Networks: A small-sized neural network is built and trained to identify directional command inputs from head movements. Optimization for real-time operations was accomplished on microcontrollers with TensorFlow Lite, which enabled smooth execution during real-time interactions.

4. Detection of Safety Risks and Obstacles: Obstacle detection in the vehicle's path was done by the use of ultrasonic sensors (HC-SR04). Algorithms that prevent collision would stop motion whenever the distance is below a specific number.

5. Testing on users and incorporating feedback: The system was tested with five participants diagnosed with upper-limb paralysis. Discomfort levels, control accuracy and fatigue among participants were captured through systematic questioning.

2. VEHICLE DESIGN

Main Parts:

- **Arduino Uno:** It gathers readings of the attached sensors, resolves the gathered data and then switches on the relays to perform the relevant tasks.
- **Power Source:** This supplies power to the Arduino Uno. It can come from a USB connection, battery, or external adapter.
- **Battery:** This gives extra power needed for the wiper motors; they require more voltage than the Arduino needs.

Sensors:

- **Gyroscopic Sensor:** Documents the rotational speed of something and defines its head movements.
- **Ultrasonic Sensor:** An ultrasonic sensor sends out a sound wave and sends it back if this wave collides with an object. It enables us to avoid any possible colliding within the object.

Output Devices:

- **Relay 1 and Relay 2:** They are the switches used by the Arduino to control devices that need more power, like wiper motors. Arduino sends a low-power signal to the relay, which then allows high power from the battery to move to the motor.

- **Wiper Motor 1 and Wiper Motor 2:** Sometimes, parts of the system came to life whenever the relays gained power.

Connection Process:

- **Sensors to Arduino:** The Arduino Uno's control unit receives information from the gyroscopic and ultrasonic sensors.
- **Power to Arduino:** It is the power supply that gives power to the Arduino to maintain its operation.
- **Arduino to Relays:** When receiving sensor data, the Arduino analyses it, using its pre-defined logic, and which relay to use, 1 or 2 depending on the analysis.
- **Battery to Relays:** The relays depend on the battery for energy to activate.
- **Relays to Motors:** With the relays fired up by the Arduino, the battery powers the wiper motors, which then turn it forward.

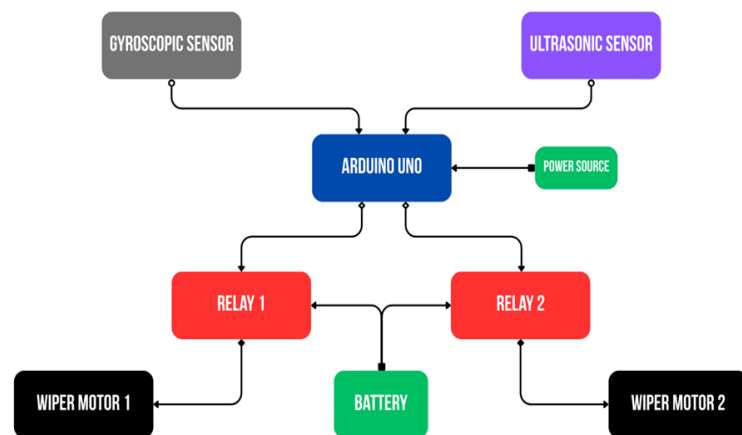


Fig. 1: Circuit Block Diagram



Fig. 2: Wheelchair CAD Model

Components:

Wiper Motor: The wiper motors are made for durability and longevity, meaning that they can withstand frequent operations without overheating and wearing out fast, thus complementing the robustness of the wheelchair system. Being low-voltage, these motors run on less output power, thus integrating easily into the wheelchair battery system without demanding excessive energy, thus helping extend the total battery life. Keeping their cost low, they also contribute towards the overall cost of the device-within-reach vis-à-vis their vision of making the assistive technology more widely available. Windshield wiper motors are typically powered by 12v DC, they cause wiper blades to move back and forth.

Gyroscopic sensor: Gyroscopic sensors are essential for steering a wheelchair controlled by head movements. The utmost sensitivity of such sensors can transform even the slightest head movements into smooth and natural movements of a wheelchair that empowers a user with quadriplegia to exercise independence. Due to the sensors' precision and swiftness, the wheelchair adjusts to the action of its user, thus improving their everyday reliability in self-reliance.

Arduino Uno: The UNO, as the first Arduino USB board and a key part of the Arduino Software ecosystem, is characterized by its simplicity, multitude of connections, and shield support. The important features of the Arduino UNO include 6 analogue inputs, 14 digital outputs, a USB connector, a power supply connector and an ICSP header. There's the Arduino IDE, which is used by programmers to write code, and this software works on both online/offline systems.

Ultrasonic Sensor: HC-SR04 is reliable at short range, up to about 4 meters. Typical applications for this sensor are parking sensors, obstacle avoidance in robotics and interactive installations. The HC-SR04 module contains an ultrasonic transmitter, receiver and the control circuit. The sensor projects an ultrasonic frequency in the form of a sound wave and listens to the echo of its wave obtained from the nearby target object. By detecting the time required for the sound wave to reach the target and return, the module calculates the distance based. It is simple to reserve Arduino or ESP32 with this module because it is connected to the standard digital I/O ports of Arduino or ESP32. When a trigger pulse of a duration less than 10 microseconds is provided to the HC-SR04, it initiates distance measurement and outputs a pulse width in direct proportion to the obtained distance value. The sensor requires a 5-volt source of power.

Relay: The Single Pole Double Throw relay is very adaptive. There is one utilitarian terminal in addition to the two output-specific terminals. One terminal can be powered while the relay isn't (Normally Closed), and the

other when it is (Normally Open). Under the current presence of the relay, its condition switches between the two circuits. You can easily switch between the two by controlling the relay. In other words, you can use the relay so that the current can flow to any of the two circuits on one's needed.

Bearing: Bearings are crucial for the smooth and reliable operation of machinery. They offer many benefits, such as reducing friction, distributing load, minimizing noise and vibration, accommodating slight misalignments, and providing flexible support.

Trolley Wheels: Trolley wheels are used for effortless transport in carts, trolleys, and industrial machinery. They have a rim, usually with an abrasive tyre for grip, sitting on a hub. Dimensions, material, and design differ according to use, ranging from light casters to heavy-duty wheels. General materials such as rubber, polyurethane, nylon, and cast-iron trade off load capacity, floor protection, and wear resistance. Polyurethane and rubber are best indoors for shock absorption and noise reduction, but metal and nylon support heavy loads and rugged terrain.

Nylon Wheels: Nylon wheels are strong and light, providing superior wear and impact resistance suitable for industrial use. Their high load-bearing capability and non-slip movement on rigid surfaces make them a trustworthy option.

3. WORKING

• **Detecting Head Movement:**

- The MPU6050 is attached to a helmet, which is then kept on the user's head.
- It measures how the head is moving and in which direction it's tilting (forward, backwards, left, or right).
- The data is conveyed to Arduino Uno.

Processing Signals and Controlling Movement:

- The Arduino Uno takes the sensor data and figures out which direction the user wants to go.
- Based on preset limits, the Arduino sends signals to the motor driver to control the motors.

Wheelchair Movement:

- Tilting head forward → Moves.
- Tilting head backwards → Moves backwards.
- Tilting head right → Turns right.
- Tilting head left → Turns left.
- No head tilt → Stops

Avoiding Obstacles:

- The proximities in front of the wheelchair are continuously being measured by the ultrasonic sensor.
- Once any object moves closer to less than 100 cm (approximately 40 inches) from the Arduino, the motors stop immediately to avoid any resulting collision.

This system allows users to control a wheelchair using head movements in a hands-free, efficient, and safe way.



Fig. 3: Wheelchair Model

4. OBSERVATIONS

- The wired connection eliminates Bluetooth interference, ensuring stable communication throughout the circuit.
- The gyroscopic sensor provides precise motion control for smooth navigation.
- The obstacle detection mechanism successfully prevents collisions.

5. FUTURE SCOPE

- **Advanced User Interfaces:** Integrate voice recognition for hands-free control.
- **Brain-Computer Interfaces (BCI):** Explore BCI for direct neural control.
- **Enhanced Safety Features:** Implement redundant sensors (e.g., multiple ultrasonic sensors, LiDAR) for improved obstacle detection.
- **Fall Detection:** Integrate sensors to detect falls and trigger emergency responses.
- **Emergency Stop Mechanisms:** Design robust and easily accessible emergency stop mechanisms.
- **GPS Tracking:** Implement GPS tracking for outdoor navigation and location monitoring.

- **Improved Device Design:** Data can be used to improve the design and functionality of future wheelchair models.

6. CONCLUSIONS

The state of quadriplegia refers to an inability to use any of the four limbs at all, as a result of both loss of sensory and motor functions and extremely poor mobility. As an answer to the challenge, engineers got a device that controlled a wheelchair using head motions. The wheelchair provides strong torque when moving slowly while it is equipped with an accelerometer-lined helmet for navigation up ramps and slopes.

As the model we built is a prototype model, we designed a wheelchair by using sensors like gyroscopic sensor, ultrasonic sensor, Arduino UNO, SPDT relays, wiper motors & load cells. By integrating all these electronic components and mounting them on the manufactured wheelchair, we were able to get the desired results like moving forward/backwards, turning left/right and a 360-degree turn. Since the wheelchair uses a wiper motor, it gives high torque and low speed, which is best suitable for the patients. Not only can the project expand its wired wiring setup for gyroscopic sensor and Arduino communication, but also, one could use wireless technologies, implementing Brain-Computer Interface (BCI) and AI-driven gesture recognition, among others.

In the end, this project increases reliability and responsiveness, making it simple to use and increasing independence and quality of life for differently-abled patients.

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