An-Najah National University

Faculty of Engineering & Information Technology

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Graduation Project II Report

Smart Glove Controlled Wheelchair

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Disclaimer

This report was prepared by [Nagham Fraij] and [Akram Abu Aisheh] from the Department of Computer Engineering, Faculty of Engineering and Information Technology, An-Najah National University. It has not been edited or corrected, except for editorial revisions resulting from the evaluation process. Therefore, it may contain linguistic or technical errors.

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Abstract

People with mobility impairments often face difficulties using traditional wheelchair control systems, especially when operating joysticks or manual controls. This project presents a Smart Glove Controlled Wheelchair that enables users to control wheelchair movement through simple hand gestures. The proposed system consists of two main units: a glove unit and a wheelchair unit.

The glove unit is equipped with an Arduino Nano, an MPU6050 motion sensor, and an HC-05 Bluetooth module. The MPU6050 detects the orientation and movement of the user's hand, while the Arduino Nano processes the sensor readings and converts them into movement commands. These commands are transmitted wirelessly via Bluetooth to the wheelchair unit.

The wheelchair unit consists of an Arduino Nano, an HC-05 Bluetooth module, an L298N motor driver, DC motors, an HC-SR04 ultrasonic sensor, and a buzzer. Upon receiving commands, the system controls the wheelchair movement in different directions, including forward, backward, left, right, and stop. In addition, the ultrasonic sensor continuously monitors the surrounding environment and detects obstacles to improve user safety by preventing collisions.

The proposed system provides a low-cost, reliable, and user-friendly assistive mobility solution. It enhances user independence and demonstrates the practical integration of embedded systems, wireless communication, and sensor technologies in healthcare and assistive applications.

Chapter 1: Introduction

1.1 General Background

Mobility plays a vital role in the daily lives of individuals, especially for people with physical disabilities who depend on wheelchairs for movement and independence. Traditional wheelchairs often rely on manual operation or joystick-based control systems, which may not be suitable for all users due to limited hand strength, mobility restrictions, or other physical challenges.

Recent advances in embedded systems, wireless communication, and sensor technologies have enabled the development of intelligent assistive devices that provide more convenient and user-friendly control methods. Gesture-based control systems have gained significant attention because they allow users to interact with devices naturally through simple hand movements.

This project presents a Smart Glove Controlled Wheelchair that utilizes hand gestures to control wheelchair movement. The system combines an MPU6050 motion sensor, Arduino Nano microcontrollers, Bluetooth communication, and obstacle detection technology to provide a safe, efficient, and low-cost mobility solution. By translating hand movements into wheelchair commands, the proposed system improves user independence, comfort, and accessibility while enhancing safety through obstacle detection and warning mechanisms.

Figure 1: Chapter 1: Introduction

1.1 Problem Statement

- Many individuals with physical disabilities face difficulties in controlling traditional wheelchairs due to limitations in mobility, muscle strength, or coordination. Conventional control methods, such as manual operation or joystick-based systems, may not be suitable for all users and often require continuous physical effort.
- As assistive technologies continue to evolve, there is an increasing need for intelligent and user-friendly mobility solutions that provide greater independence and ease of use. Therefore, the challenge addressed in this project is the development of a smart wheelchair control system that utilizes simple hand gestures instead of traditional control mechanisms.
- The proposed system aims to provide a reliable, low-cost, and safe method for wheelchair control by integrating motion sensing, wireless communication, and obstacle detection technologies. This approach

improves accessibility, reduces user effort, and enhances overall mobility and safety.

1.2 Objectives

The main objective of this project is to develop a Smart Glove Controlled Wheelchair that enables users to control wheelchair movement through simple hand gestures in a safe, efficient, and user-friendly manner.

The specific objectives of the project are:

1. To design and implement a wearable glove capable of detecting hand movements and gestures.
2. To utilize the MPU6050 motion sensor for measuring hand orientation and movement accurately.
3. To establish wireless communication between the glove and the wheelchair using HC-05 Bluetooth modules.
4. To control wheelchair movement in different directions, including forward, backward, left, right, and stop.
5. To integrate an obstacle detection system using an HC-SR04 ultrasonic sensor to improve user safety.
6. To provide warning alerts through a buzzer when obstacles are detected.
7. To develop a low-cost and reliable assistive mobility solution for individuals with physical disabilities.
8. To demonstrate the practical application of embedded systems, wireless communication, and sensor technologies in healthcare and assistive devices.

1.3 Scope of Work

The scope of this project includes the design, implementation, and testing of a Smart Glove Controlled Wheelchair system. The project focuses on developing a gesture-based control mechanism that enables users to control wheelchair movement through simple hand motions.

The project scope includes:

1. Designing a wearable glove equipped with motion sensing technology.
2. Integrating the MPU6050 sensor to detect hand orientation and movement.
3. Establishing wireless communication between the glove unit and the wheelchair unit using HC-05 Bluetooth modules.
4. Developing a wheelchair control system capable of executing movement commands such as forward, backward, left, right, and stop.
5. Implementing an obstacle detection system using the HC-SR04 ultrasonic sensor to prevent collisions.
6. Providing audio warning notifications through a buzzer when obstacles are detected.
7. Testing and validating the performance of the system under different operating conditions.

The project does not include autonomous navigation, GPS tracking, voice control, or artificial intelligence-based decision making. These features may be considered as future enhancements.

1.4 Significance

The Smart Glove Controlled Wheelchair provides an innovative and practical solution for individuals with physical disabilities who face difficulties using conventional wheelchair control systems. By utilizing hand gestures as a control method, the system offers a more natural and convenient way of interacting with the wheelchair, reducing the physical effort required from the user.

The project contributes to improving the independence and mobility of wheelchair users by allowing them to control movement through simple hand motions. In addition, the integration of obstacle detection technology enhances user safety by reducing the risk of collisions and accidents during operation.

Furthermore, the project demonstrates the effective application of embedded systems, wireless communication, and sensor technologies in assistive healthcare solutions. The proposed system is designed to be low-cost, reliable, and easy to implement, making it a suitable alternative to more expensive commercial smart wheelchair systems.

This project also serves as an educational platform for applying engineering concepts related to microcontrollers, sensors, motor control, and wireless communication in a real-world application that addresses an important social and healthcare need.

1.5 Organization of the Report

This report is organized into six chapters. Chapter One presents an introduction to the project, including the problem statement, project objectives, scope of work, significance, and overall motivation behind the proposed system.

Chapter Two discusses the constraints and limitations encountered during the development of the project, the standards and software tools used, and the coursework that contributed to the successful completion of the project.

Chapter Three presents a literature review of related studies and existing smart wheelchair systems, focusing on gesture-based control, wireless communication, and obstacle detection technologies.

Chapter Four describes the project methodology in detail, including the system structure, hardware components, communication system, motion detection mechanism, obstacle detection system, and the overall operation of the proposed system.

Chapter Five presents the experimental results, testing procedures, system performance evaluation, and discussion of the obtained results.

Finally, Chapter Six summarizes the project, presents the conclusions, and discusses possible future improvements and enhancements that can be implemented in future versions of the system.

Chapter 2: Theoretical Background and Previous Work

2.0 Microcontrollers and Main Control Unit

2.0 Microcontrollers and Main Control Unit

The system uses Arduino Nano boards as the main control units. One Arduino Nano is placed in the glove unit to read the MPU6050 sensor and send commands. A second Arduino Nano is placed in the wheelchair unit to receive commands and control the motors.

Arduino Nano was selected because it is small, affordable, easy to program, and suitable for compact embedded systems and wearable prototypes.

Arduino Nano is based on the ATmega328P microcontroller and operates at a clock frequency of 16 MHz. It provides 14 digital input/output pins, 8 analog input pins, and supports serial, SPI, and I2C communication protocols. Due to its compact size and low power consumption, Arduino Nano is widely used in wearable electronics, robotics, and embedded system applications.

In this project, two Arduino Nano boards are used. The first board is installed in the glove unit and is responsible for reading MPU6050 sensor data, processing hand gestures, and transmitting commands through Bluetooth. The second board is installed in the wheelchair unit and is responsible for receiving commands, controlling the motor driver, monitoring the ultrasonic sensor, and activating the buzzer when necessary.

The use of two separate microcontrollers improves system organization and allows independent operation of the transmitter and receiver units, resulting in a more reliable and modular design. In addition, the Arduino Nano platform provides a large development community, extensive documentation, and numerous software libraries, which simplifies system development and troubleshooting.

The microcontroller acts as the central processing unit of the system by coordinating communication between sensors, wireless modules, and motor control circuits. Without the Arduino Nano, the various hardware components would not be able to communicate effectively or execute the required wheelchair movement commands.

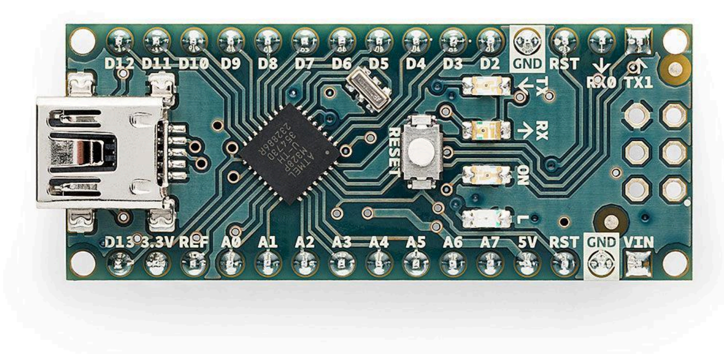

Figure 2: Chapter 2: Theoretical Background and Previous Work

2.1 Motion Sensing Using MPU6050

The MPU6050 is a motion tracking module that combines a three-axis accelerometer and a three-axis gyroscope in a single compact device. The accelerometer measures linear acceleration and detects the direction of gravity, while the gyroscope measures angular velocity and rotational movement. By combining the outputs of both sensors, accurate motion and orientation measurements can be obtained.

In this project, the MPU6050 is mounted on the smart glove and serves as the primary input device for wheelchair control. The sensor continuously monitors the orientation of the user's hand and sends motion data to the Arduino Nano through the I2C communication protocol using the SDA and SCL pins.

The Arduino processes the sensor readings and compares them with predefined threshold values. When the user's hand tilts forward, backward, left, or right beyond the specified threshold, the system interprets the movement as a wheelchair command. Each gesture is then converted into a specific movement instruction and transmitted wirelessly to the wheelchair unit through Bluetooth communication.

One of the major advantages of the MPU6050 is its ability to provide real-time motion tracking while maintaining low power consumption. In addition, the sensor is compact, lightweight, inexpensive, and widely supported by Arduino libraries, making it an ideal choice for wearable embedded systems.

The use of the MPU6050 allows the wheelchair to be controlled naturally through hand gestures without requiring joysticks, buttons, or complex input devices. This improves user comfort and makes the control system more intuitive and accessible for people with mobility impairments.

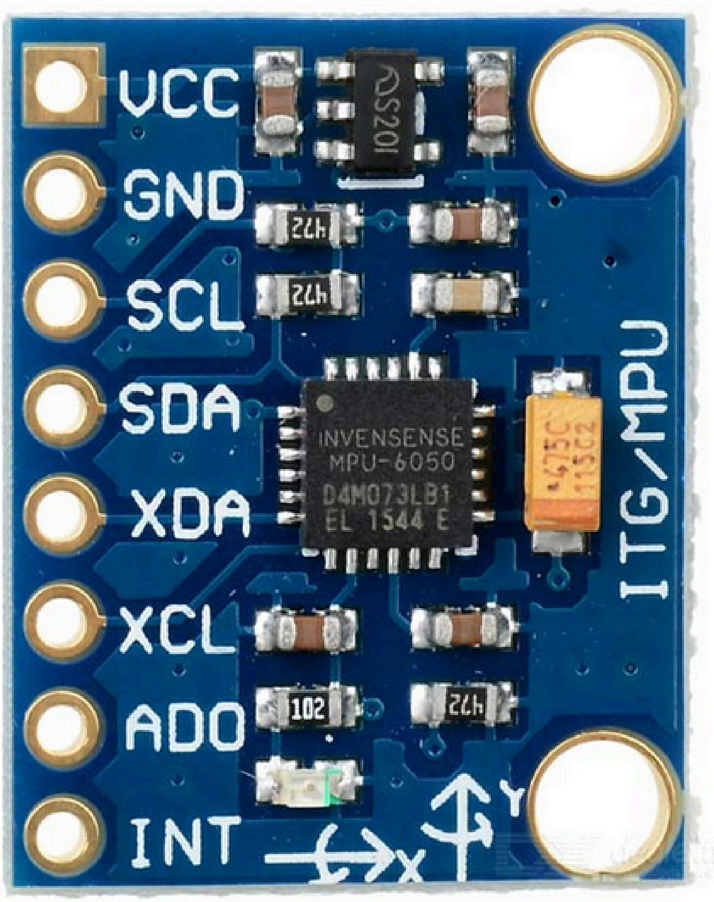

Figure 3: 2.1 Motion Sensing Using MPU6050

2.2 Wireless Communication

Wireless communication is an essential part of the Smart Glove Controlled Wheelchair system because it enables communication between the glove unit and the wheelchair unit without the need for physical wires. In this project, HC-05 Bluetooth modules are used to establish a reliable wireless connection between the transmitter and receiver systems.

The HC-05 module is a low-cost Bluetooth communication device that supports serial communication and can operate in both Master and Slave modes. One HC-05 module is installed on the glove unit, while another module is installed on the wheelchair unit. The glove module transmits movement commands generated by the Arduino Nano, and the wheelchair module receives these commands and forwards them to the receiving Arduino Nano for processing.

Communication between the Arduino Nano and HC-05 module is achieved using UART serial communication. Simple command characters are transmitted to represent different wheelchair movements. For example, a specific character can represent forward movement, while other characters represent backward movement, left turn, right turn, or stop commands. This method reduces communication complexity and improves system response time.

Bluetooth technology was selected because it provides sufficient communication range for the intended application, consumes relatively low power, and can be easily integrated with Arduino-based systems. Additionally, Bluetooth modules are widely available, affordable, and require minimal configuration compared to other wireless communication technologies.

The wireless communication system improves user comfort by eliminating cables between the glove and the wheelchair. It also increases mobility and flexibility, allowing the user to control the wheelchair naturally through hand gestures while maintaining a stable and responsive connection.

Figure 4: 2.2 Wireless Communication

2.3 Motor Driving System

The L298N motor driver is used as the main motor control interface in the Smart Glove Controlled Wheelchair system. Since the Arduino Nano cannot supply enough current and voltage to drive DC motors directly, the L298N module acts as an intermediate circuit between the microcontroller and the motors.

The L298N is a dual H-bridge motor driver capable of controlling two DC motors independently. It allows the Arduino Nano to control both the direction and operation of each motor by sending digital control signals to the driver inputs. Based on these signals, the motor driver can rotate the motors forward, reverse their direction, stop them, or create turning movements.

In this project, the Arduino Nano receives movement commands from the Bluetooth module and translates them into motor control signals. These signals are then sent to the L298N motor driver, which supplies the necessary power to the motors. When both motors rotate in the same direction, the wheelchair moves forward or backward. When the motors rotate differently, the wheelchair turns left or right.

One of the major advantages of the L298N module is its ability to handle higher motor currents while protecting the microcontroller from excessive electrical loads. It also provides a simple and reliable interface for controlling multiple motors using a small number of Arduino pins.

The motor driver plays a critical role in converting electronic control commands into physical wheelchair movement. Without the L298N module, the Arduino Nano would not be capable of directly operating the motors required for the wheelchair prototype.

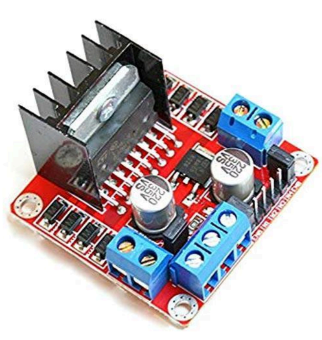

Figure 5: 2.3 Motor Driving System

2.4 DC Motors and Wheel Movement

DC motors are responsible for generating the mechanical movement of the Smart Glove Controlled Wheelchair. These motors convert electrical energy supplied by the battery and motor driver into rotational motion, allowing the wheelchair to move in different directions according to the user's hand gestures.

In this project, a differential drive mechanism is used, where two DC motors are mounted on opposite sides of the wheelchair chassis. Each motor controls one wheel independently. By adjusting the direction of rotation of each motor, the wheelchair can move forward, backward, turn left, turn right, or stop.

When both motors rotate forward at the same time, the wheelchair moves forward. Similarly, when both motors rotate in the reverse direction, the wheelchair moves backward. Turning movements are achieved by changing the rotation direction or speed of one motor relative to the other. For example, turning right can be achieved by slowing down or reversing the right motor while maintaining the movement of the left motor.

The use of DC motors provides a simple and effective solution for wheelchair movement. They are widely used in robotic and embedded systems due to their low cost, ease of control, and compatibility with motor driver modules such as the L298N.

The movement performance of the wheelchair depends on several factors, including motor torque, wheel size, battery capacity, and chassis design. Proper motor selection is essential to ensure stable movement and reliable operation of the wheelchair prototype.

Figure 6: 2.4 DC Motors and Wheel Movement

2.5 Obstacle Detection

Obstacle detection is an important safety feature in the Smart Glove Controlled Wheelchair system. To prevent collisions and ensure safe operation, an HC-SR04 ultrasonic sensor is used to continuously monitor the area in front of the wheelchair and detect nearby objects.

The HC-SR04 operates by transmitting ultrasonic sound waves and measuring the time required for the reflected echo to return from an obstacle. Using this time measurement, the Arduino Nano calculates the distance between the wheelchair and the detected object. This method provides a simple and effective way to measure distances without physical contact.

In this project, the ultrasonic sensor is mounted at the front of the wheelchair to monitor the path ahead. The Arduino continuously reads the distance measurements and compares them with a predefined safety threshold. If an obstacle is detected within the specified safety distance, the system immediately stops the wheelchair movement and activates the buzzer to alert the user.

The obstacle detection system improves overall user safety by reducing the risk of accidental collisions. It is particularly useful when the user is focused on controlling the wheelchair through hand gestures and may not immediately notice obstacles in the environment.

The HC-SR04 sensor was selected because it is inexpensive, easy to interface with Arduino Nano, and capable of providing accurate distance measurements over a practical range. These characteristics make it suitable for embedded safety systems and robotic mobility applications.

By integrating obstacle detection with the gesture-based control system, the wheelchair becomes safer and more reliable for daily operation.

Figure 7: 2.5 Obstacle Detection

2.6 Alert and Power System

The alert and power system plays an important role in ensuring the safe and reliable operation of the Smart Glove Controlled Wheelchair. This subsystem consists mainly of a buzzer for warning notifications and portable power sources that supply electrical energy to both the glove unit and the wheelchair unit.

A buzzer is used as an audible warning device to notify the user whenever an obstacle is detected within the predefined safety distance. When the ultrasonic sensor identifies an object that may cause a collision, the Arduino Nano activates the buzzer to produce a warning sound. This immediate feedback helps the user become aware of potential hazards and improves overall operational safety.

In addition to the warning system, an appropriate power supply is required for all electronic components. The glove unit can be powered using a small battery or a portable power bank that provides sufficient energy for the Arduino Nano, MPU6050 sensor, and HC-05 Bluetooth module. Since these components consume relatively low power, a lightweight portable power source is adequate for extended operation.

The wheelchair unit requires a larger power source because it must supply energy to the Arduino Nano, Bluetooth module, ultrasonic sensor, buzzer, motor driver, and DC motors. A battery pack is therefore used to provide stable voltage and sufficient current for continuous operation of the entire system.

Proper power distribution is essential to ensure reliable system performance. Voltage fluctuations or insufficient battery capacity may affect sensor readings, communication reliability, and motor performance. Therefore, selecting an appropriate power source is an important factor in the overall design of the wheelchair prototype.

The combination of the buzzer and power supply system improves both safety and functionality, ensuring that the user receives warning notifications while maintaining stable operation of all hardware components.

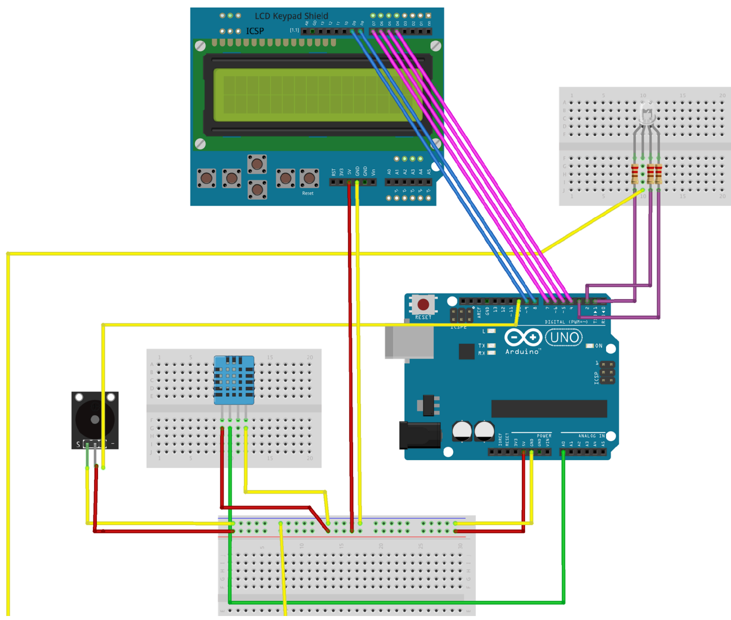

Figure 8: 2.6 Alert and Power System

2.7 Chassis and Mechanical Structure

The mechanical structure serves as the physical foundation of the Smart Glove Controlled Wheelchair system. It provides support for all electronic components, motors, wheels, batteries, and sensors while ensuring stability during operation.

In this project, a wooden chassis is used as the main structural frame of the wheelchair prototype. Wood was selected because it is inexpensive, lightweight, easy to cut, and simple to modify during the design and testing phases. These characteristics make it suitable for prototype development and educational projects.

The chassis is designed to accommodate all system components in an organized manner. The DC motors are securely mounted to the frame and connected to the driving wheels. The Arduino Nano, L298N motor driver, Bluetooth module, battery pack, ultrasonic sensor, and buzzer are positioned strategically to optimize weight distribution and maintain system stability.

Proper arrangement of components is important to prevent interference between moving and stationary parts. Wiring must be organized carefully to avoid contact with the wheels or motors during operation. The ultrasonic sensor is mounted at the front of the wheelchair to provide an unobstructed field of view for obstacle detection, while the battery pack is positioned to maintain balance and provide stable power distribution.

The mechanical design also contributes to the overall safety and reliability of the system. A stable chassis reduces vibration effects on sensors, improves motor performance, and enhances movement accuracy. Furthermore, the modular structure allows easy maintenance and future modifications, such as adding new sensors, upgrading the motor system, or improving the wheelchair frame.

Although the current prototype is intended primarily for testing and demonstration purposes, the mechanical structure successfully supports all project components and provides a practical platform for implementing the smart wheelchair system.

Figure 9: 2.7 Chassis and Mechanical Structure

Chapter 3: Constraints, Standards and Methodology

3.1 Design Constraints

Several constraints influenced the design and implementation of the Smart Glove Controlled Wheelchair. These constraints were considered during the development process to ensure that the system remains functional, affordable, and suitable for prototype testing.

One of the primary limitations is the communication range of the HC-05 Bluetooth modules. Since Bluetooth communication operates over a limited distance, the glove and wheelchair units must remain within the effective communication range to maintain reliable control.

Another important constraint is the sensitivity of the MPU6050 motion sensor. Hand vibrations, unintended movements, or incorrect calibration may affect sensor readings and generate inaccurate control commands. Therefore, appropriate threshold values must be selected to distinguish between intentional and unintentional hand movements.

The wheelchair prototype is built on a wooden chassis designed primarily for testing and demonstration purposes. Although the structure is sufficient for prototype development, it is not intended to support heavy loads or long-term real-world operation.

Battery capacity also affects system performance. The operating time of both the glove unit and the wheelchair unit depends on the available battery power. Insufficient battery capacity may reduce system reliability and operating duration.

The ultrasonic sensor used for obstacle detection mainly monitors the area directly in front of the wheelchair. As a result, obstacles located on the sides or behind the wheelchair may not be detected by the current system configuration.

In addition, environmental conditions such as uneven surfaces, sensor noise, electrical interference, and communication delays may affect overall system performance. Despite these limitations, the proposed design successfully demonstrates the feasibility of gesture-based wheelchair control using low-cost embedded system components.

3.2 Standards and Impacts

The Smart Glove Controlled Wheelchair was designed according to basic engineering principles and low-voltage embedded system standards. Special attention was given to electrical safety, component compatibility, communication reliability, and user protection during operation.

From an electrical perspective, all components operate at safe low-voltage levels suitable for educational and prototype applications. Proper wiring practices were followed to minimize the risk of short circuits, voltage drops, and unstable connections. Common ground connections were established between the Arduino Nano, motor driver, sensors, and communication modules to ensure reliable operation.

The software implementation follows standard Arduino programming practices. Modular programming techniques were used to separate sensor reading, Bluetooth communication, obstacle detection, and motor control functions. This improves code readability, maintainability, and future system expansion.

The project also considers important social and technological impacts. From a social perspective, the proposed system aims to improve mobility and independence for individuals with physical disabilities by providing a more natural and intuitive wheelchair control method. Gesture-based control reduces the need for traditional joysticks and allows users to interact with the wheelchair through simple hand movements.

From an educational perspective, the project demonstrates the integration of multiple engineering disciplines, including embedded systems, sensor interfacing, wireless communication, motor control, and mechanical design. It provides valuable practical experience in both hardware and software development.

Economically, the proposed system is based on low-cost and widely available components such as Arduino Nano, HC-05 Bluetooth modules, MPU6050 sensors, and ultrasonic sensors. This makes the solution more affordable compared to many commercial smart wheelchair systems.

Overall, the project highlights how modern embedded technologies can be utilized to create assistive devices that improve quality of life while remaining cost-effective and technically feasible.

3.2.5 Health and Safety

Health and safety considerations are essential in the design and operation of the Smart Glove Controlled Wheelchair. Since the system involves electrical components, moving motors, and user interaction, appropriate safety measures must be implemented to ensure reliable and secure operation.

All electrical connections should be properly insulated and checked before powering the system. Loose wires, short circuits, or incorrect connections may damage electronic components or cause system malfunction. Therefore, all wiring should be tested carefully during assembly and maintenance.

Battery safety is another important consideration. The battery pack must be selected according to the voltage and current requirements of the motors and electronic components. Overloading the battery or using an inappropriate power source may reduce system performance and create potential safety risks.

The wheelchair should automatically stop when the user's hand returns to the neutral position. This safety mechanism reduces the possibility of unintended movement and provides better control during operation. In addition, if Bluetooth communication is interrupted or lost, the system should stop the motors immediately to prevent uncontrolled movement.

The HC-SR04 ultrasonic sensor contributes significantly to user safety by continuously monitoring the area in front of the wheelchair. When an obstacle is detected within the predefined safety distance, the Arduino Nano immediately stops the motors and activates the buzzer to alert the user. This helps prevent collisions and improves overall system reliability.

Before operating the wheelchair at full speed, all components should be tested individually and as a complete system. Initial testing should be performed at low speed and in a controlled environment to verify correct operation and ensure user safety.

For future development, additional safety features such as emergency stop buttons, multiple obstacle sensors, battery monitoring systems, and communication failure detection mechanisms can be integrated to further improve system safety and reliability.

3.3 Hardware and Software Components

The Smart Glove Controlled Wheelchair consists of several hardware and software components that work together to achieve gesture-based wheelchair control.

Hardware Components

- **Arduino Nano (2 units):** Used as the main control units for the glove and wheelchair systems.
- **MPU6050 Sensor:** Detects hand movement and orientation using an accelerometer and gyroscope.

- **HC-05 Bluetooth Modules (2 units):** Provide wireless communication between the glove and wheelchair units.
- **L298N Motor Driver:** Controls the operation and direction of the DC motors.
- **DC Motors:** Generate the mechanical movement required for wheelchair motion.
- **HC-SR04 Ultrasonic Sensor:** Detects obstacles in front of the wheelchair to improve safety.
- **Buzzer:** Produces audible warning signals when obstacles are detected.
- **Power Sources:**
    - Battery or power bank for the glove unit.
    - Battery pack for the wheelchair unit.
- **Wooden Chassis:** Serves as the structural frame supporting all electronic and mechanical components.

Software Components

- **Arduino IDE:** Used for writing, compiling, and uploading code to the Arduino Nano boards.
- **Glove Unit Firmware:**
    - Reads MPU6050 sensor data.
    - Interprets hand gestures.
    - Sends movement commands via Bluetooth.
- **Wheelchair Unit Firmware:**
    - Receives Bluetooth commands.
    - Controls the motor driver and DC motors.
    - Monitors obstacle detection.
    - Activates safety features such as the buzzer and emergency stop.

System Integration

- Combines all hardware and software components into a single functional system.
- Enables efficient gesture-based wheelchair control.

- Provides a practical and safe wheelchair prototype for users with mobility limitations.

3.3.1 Mobile Application Interface

In addition to the gesture-based control system, a mobile application was used to provide an alternative method for controlling the wheelchair through Bluetooth communication. The application establishes a wireless connection with the HC-05 Bluetooth module installed on the wheelchair unit.

The user can connect to the wheelchair by selecting the paired Bluetooth device from the available device list. Once connected, movement commands can be transmitted directly from the smartphone to the Arduino Nano.

The application provides several control buttons, including Forward, Backward, Left, Right, and Stop. Each button sends a specific command through Bluetooth communication, allowing the wheelchair to respond accordingly.

This mobile application was mainly used for system testing, debugging, and verifying motor functionality during development. It also provides an alternative control method that may be useful for future system improvements and accessibility applications.

Figure 10: Mobile Application Control Interface

3.4 Procedures

The implementation of the Smart Glove Controlled Wheelchair was carried out through a series of organized stages to ensure proper integration of all hardware and software components. Each subsystem was developed and tested individually before being integrated into the final prototype.

The first stage involved assembling the glove unit. The Arduino Nano, MPU6050 sensor, and HC-05 Bluetooth module were connected and mounted on the glove. The MPU6050 sensor was configured to continuously monitor hand movements and orientation. Sensor readings were then analyzed to identify specific hand gestures corresponding to wheelchair movement commands.

The second stage focused on developing the wireless communication system. The HC-05 Bluetooth modules were configured to establish a stable communication link between the glove unit and the wheelchair unit. Communication tests were performed to verify the successful transmission and reception of control commands.

The third stage involved constructing the wheelchair prototype. The wooden chassis was assembled, and the DC motors were mounted securely to the frame. The L298N motor driver was connected to the motors and Arduino Nano to enable movement control.

The fourth stage involved integrating the safety system. The HC-SR04 ultrasonic sensor was installed at the front of the wheelchair to detect nearby obstacles. The buzzer was connected to provide warning signals whenever an obstacle was detected within the predefined safety distance.

After completing the hardware assembly, the software for both Arduino Nano boards was developed and uploaded. The transmitter program was responsible for reading sensor data and sending commands, while the receiver program controlled motor movement and monitored obstacle detection.

Finally, individual subsystem testing was performed, followed by complete system testing. The wheelchair was tested under different operating conditions to verify correct gesture recognition, Bluetooth communication, motor response, obstacle detection, and overall system reliability.

3.4.1 Glove Unit Workflow

The glove unit represents the transmitter side of the Smart Glove Controlled Wheelchair system. Its main function is to read the user's hand movement and convert it into control commands that can be sent wirelessly to the wheelchair unit.

When the glove unit is powered on, the Arduino Nano initializes the MPU6050 sensor and the HC-05 Bluetooth module. The MPU6050 continuously measures the orientation and tilt of the user's hand. These readings are collected by the Arduino Nano through the I2C communication protocol.

The Arduino compares the sensor readings with predefined threshold values to determine the direction of hand movement. If the hand is tilted forward, the Arduino generates a forward command. If the hand is tilted backward, a backward command is generated. Similarly, right and left tilts are converted into right and left movement commands. When the hand remains in the neutral position, the system generates a stop command.

After identifying the correct gesture, the Arduino Nano sends the corresponding command through the HC-05 Bluetooth module to the wheelchair unit. This process is repeated continuously to provide real-time control of the wheelchair based on the user's hand movements.

3.4.2 Wheelchair Unit Workflow

The wheelchair unit represents the receiver side of the Smart Glove Controlled Wheelchair system. Its primary function is to receive movement commands from the glove unit, process them, and control the wheelchair motors accordingly.

When the wheelchair unit is powered on, the Arduino Nano initializes the HC-05 Bluetooth module, the L298N motor driver, the HC-SR04 ultrasonic sensor, and the buzzer. The Arduino continuously listens for incoming Bluetooth commands transmitted by the glove unit.

Once a command is received, the Arduino interprets the instruction and determines the required wheelchair movement. Before executing the command, the system checks the distance measured by the ultrasonic sensor to ensure that no obstacle is present within the predefined safety range.

If the path is clear, the Arduino sends control signals to the L298N motor driver, which activates the DC motors and performs the requested movement. The wheelchair can move forward, move backward, turn left, turn right, or stop depending on the received command.

If an obstacle is detected within the safety threshold, the Arduino immediately stops the motors and activates the buzzer to warn the user. This safety mechanism helps prevent collisions and protects both the user and the wheelchair system.

The wheelchair unit continuously repeats this process, ensuring real-time response to hand gestures while maintaining safe operation through obstacle monitoring and warning functions.

3.4.3 Gesture Command Mapping

Gesture command mapping is the process of converting specific hand movements into corresponding wheelchair control commands. This mapping system was designed to be simple, intuitive, and easy for the user to remember. The wheelchair responds directly to the direction of the user's hand movement, creating a natural and user-friendly control mechanism.

The MPU6050 sensor continuously monitors the orientation of the hand and provides acceleration and angular motion data to the Arduino Nano. The Arduino compares these values with predefined threshold limits to determine the intended movement direction. Once a gesture is recognized, the corresponding command is transmitted wirelessly to the wheelchair unit through the Bluetooth communication system.

To improve safety and reduce accidental movement, the neutral hand position is treated as a stop command. This means that whenever the user returns the hand to its normal position, the wheelchair immediately stops moving. This feature minimizes unintended commands and provides better control during operation.

The gesture-to-command relationship used in the project is shown in Table 1.

Hand Gesture	Command	Wheelchair Response
Tilt Forward	F	Move Forward
Tilt Backward	B	Move Backward
Tilt Right	R	Turn Right
Tilt Left	L	Turn Left
Neutral Position	S	Stop Motors

Obstacle Detected	STOP	Stop Motors and Activate Buzzer

This command mapping approach provides a reliable and efficient method for controlling the wheelchair while maintaining simplicity and ease of use for the user.

3.4.4 Calibration and Testing

Calibration and testing are essential steps in ensuring the accuracy, reliability, and safety of the Smart Glove Controlled Wheelchair system. Before normal operation, the MPU6050 sensor must be calibrated to determine the neutral hand position and establish the threshold values required for gesture recognition.

The calibration process begins by placing the user's hand in a comfortable neutral position. The Arduino Nano records the sensor readings corresponding to this position and uses them as reference values. Additional measurements are then taken while tilting the hand forward, backward, left, and right to determine the appropriate threshold limits for each movement command. These thresholds are carefully selected to minimize false detections caused by hand vibrations, sensor noise, or unintended movements.

After calibration, individual subsystem testing is performed. The MPU6050 sensor is tested to verify accurate motion detection and gesture recognition. Bluetooth communication is tested to ensure reliable transmission of commands between the glove unit and the wheelchair unit. The motor driver and DC motors are tested to confirm correct movement directions and motor responses.

The obstacle detection system is also evaluated by placing objects at different distances in front of the wheelchair. The HC-SR04 ultrasonic sensor measurements are verified, and the buzzer functionality is tested to ensure proper warning activation when obstacles are detected within the predefined safety range.

Finally, complete system testing is performed by integrating all hardware and software components. Various movement commands are executed, including forward movement, backward movement, left turns, right turns, and stop commands. The performance of the wheelchair is evaluated under different operating conditions to verify communication reliability, movement accuracy, obstacle detection performance, and overall system stability.

The testing results demonstrated that the system successfully responded to hand gestures, maintained stable Bluetooth communication, and provided effective obstacle detection, confirming the feasibility of the proposed Smart Glove Controlled Wheelchair prototype.

Chapter 4: Results and Discussion

4.1 Experimental Setup

The Smart Glove Controlled Wheelchair prototype was tested under controlled conditions to evaluate the performance of the gesture recognition system, Bluetooth communication, motor control, and obstacle detection features. The testing environment consisted of an open indoor area with sufficient space for wheelchair movement and obstacle placement.

The glove unit was powered using a portable power source and worn by the user during testing. The wheelchair unit was powered using a battery pack connected to the Arduino Nano, motor driver, sensors, and DC motors. Before each test, the HC-05 Bluetooth modules were paired successfully to establish communication between the transmitter and receiver units.

Several functional tests were conducted to evaluate system performance. These tests included forward movement, backward movement, left turn, right turn, stop mode, and obstacle detection. Each command was executed multiple times to verify consistency and communication reliability.

The ultrasonic sensor was tested using obstacles placed at different distances in front of the wheelchair. The response of the buzzer and motor stopping mechanism was observed and recorded. The experimental setup allowed the complete evaluation of all major system functions under realistic operating conditions.

4.2 Error Margin

Although the Smart Glove Controlled Wheelchair system operated successfully during testing, several factors may introduce small errors that affect system performance. These errors are common in embedded systems that rely on sensors, wireless communication, and mechanical movement.

One potential source of error is the MPU6050 sensor. Small variations in sensor readings may occur due to hand vibration, rapid movement, or sensor noise. These variations can occasionally affect gesture recognition accuracy, especially if the predefined threshold values are not properly calibrated.

Bluetooth communication may also introduce minor delays between command transmission and wheelchair response. Although these delays are generally very small, they can become noticeable if signal interference occurs or if the communication range approaches the maximum Bluetooth operating distance.

The HC-SR04 ultrasonic sensor may experience measurement inaccuracies caused by environmental conditions, object shape, surface material, or sensor positioning. These factors can slightly affect distance calculations and obstacle detection performance.

Mechanical factors such as wheel alignment, motor performance differences, battery voltage fluctuations, and surface conditions may also influence wheelchair movement accuracy. Uneven surfaces or low battery levels can affect motor response and overall system stability.

To minimize these errors, calibration procedures were performed before testing, communication links were verified, and multiple test runs were conducted to ensure consistent system performance. Despite these limitations, the overall system demonstrated reliable operation and acceptable accuracy for a prototype assistive mobility application.

4.3 Tables and Figures

The following table summarizes the relationship between hand gestures, transmitted commands, and the corresponding wheelchair responses. This mapping was used during system testing to evaluate the accuracy of gesture recognition and wheelchair movement control.

Hand Gesture	**Command**	**Wheelchair Response**
Tilt Forward	F	Move Forward
Tilt Backward	B	Move Backward
Tilt Right	R	Turn Right
Tilt Left	L	Turn Left
Neutral Position	S	Stop Motors
Obstacle Detected	STOP	Stop Motors and Activate Buzzer

Table 1 demonstrates the command mapping used throughout the testing process. The wheelchair was expected to perform the specified movement whenever the corresponding hand gesture was detected by the MPU6050 sensor.

The results obtained during testing showed that the system successfully recognized the predefined hand gestures and transmitted the correct commands through the Bluetooth communication link. The wheelchair responded appropriately to movement commands and stopped immediately when obstacles were detected within the safety threshold.

Figures included in this chapter illustrate the experimental setup, command mapping process, and the final prototype configuration. These figures provide visual confirmation of system functionality and demonstrate the successful integration of sensors, communication modules, motor control components, and safety mechanisms.

4.4 Discussion of Results

The experimental results demonstrated that the Smart Glove Controlled Wheelchair successfully achieved its primary objectives. The MPU6050 sensor was able to detect hand movements and orientations accurately, allowing the system to recognize user gestures and convert them into wheelchair movement commands.

The Bluetooth communication system provided reliable wireless data transmission between the glove unit and the wheelchair unit. During testing, movement commands were transmitted successfully with minimal delay, resulting in smooth and responsive wheelchair control.

The L298N motor driver effectively controlled the DC motors and executed the required movements. The wheelchair was capable of moving forward, backward, turning left, turning right, and stopping according to the detected hand gestures. The response of the motors was consistent throughout the testing process, demonstrating the effectiveness of the motor control system.

The obstacle detection subsystem also performed as expected. The HC-SR04 ultrasonic sensor successfully detected obstacles placed in front of the wheelchair and prevented forward movement when the safety threshold was exceeded. In addition, the buzzer provided clear audible warnings, improving user awareness and overall system safety.

Although the system performed successfully, several limitations were observed. Sensor readings may be affected by excessive hand vibration, sudden movements, or improper calibration. Bluetooth communication range is limited and may be influenced by environmental interference. Furthermore, the ultrasonic sensor only monitors the front area of the wheelchair and cannot detect obstacles from other directions.

Overall, the results confirm that the proposed Smart Glove Controlled Wheelchair is a practical and effective prototype that demonstrates the integration of motion sensing, wireless communication, motor control, and obstacle detection technologies. The system provides a simple, low-cost, and user-friendly solution for gesture-based wheelchair control and serves as a strong foundation for future development and improvement.

Chapter 5: Contribution of the Work

5.1 Contribution of the Work

The Smart Glove Controlled Wheelchair contributes to the field of assistive technology by providing an alternative method for wheelchair control using natural hand gestures. Unlike traditional joystick-based systems, the proposed solution enables users to interact with the wheelchair through simple hand movements, making the control process more intuitive and accessible.

The project demonstrates the successful integration of multiple engineering concepts, including embedded systems, motion sensing, wireless communication, motor control, and safety monitoring. By combining these technologies into a single prototype, the project provides a practical example of how modern electronic systems can be used to improve mobility and independence for individuals with physical disabilities.

From an educational perspective, the project allowed the application of theoretical knowledge gained throughout the Computer Engineering program. Concepts related to microcontrollers, sensor interfacing, communication protocols, hardware integration, software development, and system testing were implemented in a real-world engineering application.

In addition, the project contributes to the development of low-cost assistive solutions. The use of affordable and widely available components such as Arduino Nano, MPU6050, HC-05 Bluetooth modules, and ultrasonic sensors makes the system economically feasible and suitable for future development and customization.

Overall, the project serves as both an assistive mobility prototype and an educational platform that demonstrates the practical implementation of embedded systems in healthcare and accessibility applications.

5.2 Limitations and Further Study

Although the Smart Glove Controlled Wheelchair successfully demonstrates gesture-based wheelchair control, several limitations were identified during the design and testing stages. These limitations provide opportunities for future improvements and further research.

One limitation of the current system is the communication range of the HC-05 Bluetooth modules. The glove and wheelchair units must remain within the effective Bluetooth range to maintain reliable communication. Signal interruptions may affect system responsiveness and control performance.

Another limitation is the dependence on MPU6050 sensor calibration. Different users may have different hand movement patterns, which may require recalibration of threshold values to achieve accurate gesture recognition. Hand vibration and unintended movements may also affect sensor readings and command accuracy.

The obstacle detection system relies on a single HC-SR04 ultrasonic sensor positioned at the front of the wheelchair. As a result, obstacles located on the sides or behind the wheelchair cannot be detected by the current configuration. This limits the overall environmental awareness of the system.

The prototype is built on a wooden chassis primarily intended for testing and educational purposes. While the chassis is sufficient for demonstrating the project concept, it is not suitable for supporting heavy loads or long-term real-world use.

Future development of the project may include the integration of additional obstacle sensors to provide full environmental coverage, implementation of speed control using PWM techniques, addition of an emergency stop button, and incorporation of rechargeable battery management systems. Further improvements may also include mobile application support, voice control functionality, GPS tracking, and artificial intelligence algorithms for advanced gesture recognition.

Despite these limitations, the project successfully demonstrates the feasibility of controlling a wheelchair through hand gestures and provides a strong foundation for future development of smart assistive mobility systems.

Chapter 6: Conclusions and Recommendations

6.1 Conclusions

The Smart Glove Controlled Wheelchair successfully demonstrates a gesture-based approach for controlling wheelchair movement using embedded system technologies. The project integrates an MPU6050 motion sensor, Bluetooth communication modules, Arduino Nano microcontrollers, a motor driver, DC motors, and obstacle detection components into a single functional prototype.

The MPU6050 sensor accurately detects hand orientation and movement, allowing the system to convert hand gestures into movement commands. These commands are transmitted wirelessly through Bluetooth communication and executed by the wheelchair unit. The motor control system successfully performs forward, backward, left, right, and stop movements according to the received commands.

The HC-SR04 ultrasonic sensor and buzzer provide an additional layer of safety by detecting obstacles and warning the user when potential collisions may occur. This safety feature improves system reliability and reduces operational risks.

Overall, the project achieved its primary objectives and demonstrated that gesture-based wheelchair control can be implemented using low-cost and widely available embedded system components. The developed prototype provides a practical example of assistive technology that can improve mobility and independence for individuals with physical disabilities.

6.1.2 Knowledge Gained

Throughout the development of this project, several technical and practical skills were acquired. The project provided valuable experience in hardware design, software development, system integration, and troubleshooting.

The development process improved understanding of Arduino Nano programming, sensor interfacing, Bluetooth communication, motor control systems, and obstacle detection technologies. In addition, experience was gained in reading sensor data, processing signals, implementing wireless communication protocols, and controlling mechanical movement through electronic systems.

The project also strengthened problem-solving skills by requiring the identification and resolution of various hardware and software challenges. Issues related to sensor calibration, communication reliability, power distribution, and motor control were addressed during the design and testing phases.

Furthermore, the project enhanced knowledge of embedded systems engineering and demonstrated the importance of integrating multiple subsystems into a complete and functional prototype. It also provided practical experience in project planning, system testing, documentation, and teamwork.

6.3 Recommendations

The following recommendations may improve the performance and functionality of future versions of the Smart Glove Controlled Wheelchair:

- Use a stronger and more durable wheelchair chassis suitable for real-world operation.
- Implement speed control using PWM techniques to provide smoother movement.
- Add obstacle detection sensors on the sides and rear of the wheelchair.
- Integrate an emergency stop button for additional safety.
- Improve Bluetooth communication reliability and range.
- Implement rechargeable battery management and monitoring systems.
- Develop a mobile application for monitoring and configuration.
- Integrate voice control functionality for users with limited hand movement.

- Apply artificial intelligence techniques to improve gesture recognition accuracy.
- Test the system with different users and various operating environments to evaluate long-term performance.

6.4 Final Statement

In conclusion, the Smart Glove Controlled Wheelchair represents a successful implementation of a gesture-controlled assistive mobility system. By combining motion sensing, wireless communication, motor control, and obstacle detection technologies, the project demonstrates how embedded systems can be used to develop innovative solutions that improve accessibility and user independence. The prototype serves as a strong foundation for future enhancements and highlights the potential of smart assistive technologies in improving the quality of life for people with mobility challenges.

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