HAND GESTURE CONTROLLED WHEELCHAIR

PROJECT REPORT

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Submitted to the APJ Abdul Kalam Technological University in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Computer Science and Engineering

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CERTIFICATE

This is to certify that this report titled ***"HAND GESTURE CONTROLLED WHEELCHAIR"*** *is a record of bonafide PROJECT work carried out by* ***GOPIKA HARINDRAN M(MCT21CS030),MEGHANA DINESH(MCT21CS037),ABHISHEK GS(MCT21CS005),ARUN K(MCT21CS025)****during the period 2024 to 2025, under our supervision and guidance, in partial fulfilment for the award of the degree of* ***Bachelor of Technology in Computer Science & Engineering.***

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ABSTRACT

Many people in the world today suffer from paralysis, physical illness, injury or any other disability like walking difficulties. As an aid for such people, a control system is developed, with a hand motion recognition system. The system is divided into, units for movement and wheelchair. Our work aims at gaining control of a wheel chair. This wheelchair can be operated by hand movements. It consists of an accelerometer sensor that controls the user's hand motion and clarifies the user movement and moves accordingly. Depending on the direction of the acceleration, Arduino controller controls the wheelchair to move in Left, Right, Forward, & Backward directions. This system also consists of ultrasonic sensor for obstacle avoidance. For many applications used by schools, hospitals, old homes and airports the proposed wheelchair can be suggested. In addition, the SMS will be sent to the family members in case of emergency by pressing a single switch.. A critical feature of the system is its ability to send emergency alerts. If the user encounters an abnormal situation—such as a fall, collision, or sudden stop—the system automatically sends an SMS notification to the user’s family members or caregivers. This enhances safety by ensuring that help can be quickly mobilized in emergencies. To ensure safety and avoid collisions, an ultrasonic sensor is integrated into the system. This sensor helps the wheelchair detect obstacles in its path, providing the user with real-time responses and preventing potential accident .The wheelchair is equipped with sensors and a microcontroller to detect and interpret gestures accurately, translating them into directional commands (forward, backward, left, right, and stop). Additionally, an emergency alert system is embedded, which can automatically send real-time alerts to caregivers or emergency contacts when sudden stops, abnormal gestures, or hazardous events (like falls or collisions) are detected. This dual-functional design offers increased autonomy, safety, and peace of mind for users and caregivers alike.

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LIST OF ABBREVIATIONS

Sl No	Abbreviation	Full Form
1	MCU	Microcontroller Unit
2	IoT	Internet of Things
3	GSM	Global System for Mobile Communications
4	GPS	Global Positioning System
5	MEMS	Micro-Electro-Mechanical Systems
6	AI	Artificial Intelligence
7	BLE	Bluetooth Low Energy
8	PWM	Pulse Width Modulation
9	RF	Radio Frequency
10	UART	Universal Asynchronous Receiver-Transmitter
11	ADC	Analog to Digital Converter
12	USB	Universal Serial Bus
13	LED	Light Emitting Diode
14	BCI	Brain-Computer Interface
15	SLAM	Simultaneous Localization and Mapping

CHAPTER 1

INTRODUCTION

In today's world, advancements in assistive technologies play a crucial role in enhancing the quality of life for individuals with physical disabilities. Among the many mobility aids available, wheelchairs are essential for those with limited or no ability to walk due to conditions such as paralysis, illness, or injury. However, traditional wheelchairs—whether manual or electric—rely on physical effort or button-based controls, which can be difficult for users with limited hand function or strength. This limitation highlights the need for a more intuitive and accessible control system. One promising solution is gesture-based technology, which utilizes hand gestures to operate a wheelchair in a way that is user-friendly, effective, and minimizes physical strain. By enabling individuals with physical disabilities to use simple hand movements for control, this technology enhances their independence, mobility, and overall quality of life.

The proposed hand gesture-controlled wheelchair system in this study seeks to address these challenges. Using an accelerometer sensor attached to the user's hand, the system detects movement in various directions, which is then transmitted to an Arduino microcontroller. This microcontroller interprets the gestures and controls the wheelchair's movement accordingly. For example, specific gestures could be mapped to forward, backward, left, and right movements, allowing users to navigate the wheelchair intuitively without the need for manual effort or precise control. Additionally, the integration of an ultrasonic sensor helps with obstacle detection, ensuring a safer experience by automatically avoiding obstacles in the wheelchair's path. This combination of gesture control and safety features offers a practical solution for individuals with limited motor function, significantly improving their mobility and autonomy.

Gesture-based control represents a shift toward more natural and intuitive human-machine interfaces. Traditional wheelchairs often require significant manual effort or the use of a joystick, which may be difficult for some users to manage. In contrast, gesture-based systems rely on the natural movements of the user's hand, allowing for precise control with minimal physical effort. This approach is particularly beneficial for individuals with upper-body mobility limitations, as it removes the dependency on button-based controls or joysticks, which can be cumbersome or inaccessible. The proposed gesture-controlled wheelchair design focuses on both affordability and simplicity, making it accessible to a wider range of individuals while providing a comfortable and efficient alternative to traditional control methods.

The system's architecture consists of two main components: the gesture recognition module and the wheelchair control module. The gesture recognition module captures the hand movements using an accelerometer sensor, which sends the data to the control module. This module, managed by the Arduino microcontroller, processes the data and translates the hand gestures into directional commands for the wheelchair. The system is designed to be intuitive and requires minimal training, allowing users to easily control the wheelchair with natural hand gestures. This seamless interaction between the user and the wheelchair enhances usability and provides a more accessible solution for people with disabilities.

Safety is a critical consideration in the development of assistive technologies, and the proposed wheelchair system prioritizes this aspect through the integration of several safety features. An emergency alert system is included, enabling the wheelchair to send an SMS to the user's family or caregivers in case of an emergency. This feature offers peace of mind to both users and their caregivers, ensuring that help can be quickly summoned if needed. Furthermore, the ultrasonic sensor plays a key role in obstacle avoidance by detecting objects in the wheelchair's path and preventing potential collisions. This safety feature makes the wheelchair particularly suitable for use in crowded environments, such as hospitals, nursing homes, or public spaces, where navigating without bumping into obstacles is critical.

The versatility of this gesture-controlled wheelchair makes it suitable for a wide range of environments, including healthcare facilities, rehabilitation centers, and homes. Beyond benefiting users, this technology can also reduce the burden on caregivers. Individuals who rely on assistance for mobility can gain a level of independence with a gesture-controlled wheelchair, thus reducing the need for constant supervision. This could be particularly useful in healthcare settings, where quick and easy movement is essential, such as when patients need to move between rooms or wards. By promoting autonomy, the wheelchair system not only improves the user experience but also alleviates some of the caregiving responsibilities.

The use of an Arduino microcontroller in the design of the wheelchair highlights the role of embedded systems in creating accessible assistive devices. The flexibility of the Arduino platform makes it easier to integrate various sensors and modules, allowing for customization and future upgrades. This modular design ensures that the system can evolve over time, with the potential to incorporate additional gesture recognition capabilities, such as head or eye-tracking for users with limited hand movement. Furthermore, the use of Arduino allows for a cost-effective solution, making the technology more accessible to individuals in resource-constrained settings. This affordability, combined with the flexibility for further customization, makes the gesture-controlled wheelchair a promising solution for a wide range of users.

The proposed hand gesture-controlled wheelchair represents an innovative leap in assistive technology. By leveraging hand gestures for navigation, the system eliminates the need for manual controls or joysticks, making it easier for individuals with limited motor skills to operate the wheelchair. The inclusion of safety features, such as the ultrasonic sensor for obstacle detection and the emergency alert system, ensures that the wheelchair provides a secure and reliable means of mobility. This wheelchair design not only enhances the independence of users but also serves as a foundation for future innovations in assistive mobility devices. With the potential for further development, including integration with voice or facial recognition technologies, the gesture-controlled wheelchair has the capacity to significantly improve the quality of life for individuals with physical disabilities.

Mobility challenges significantly affect the quality of life for individuals with disabilities. According to the World Health Organization (WHO), over 1 billion people worldwide experience some form of disability, and a significant percentage of them require mobility assistance. Traditional wheelchairs, though useful, are often limited in functionality and require physical strength or assistance for operation. Motorized wheelchairs have emerged as a solution, but they are typically expensive and difficult to operate. Advanced motorized wheelchairs that offer joystick or voice control are limited by their high costs, complex interfaces, and the need for consistent user input. The development of more accessible and intelligent mobility solutions is crucial to ensuring that individuals with disabilities can achieve greater independence and improved quality of life.

A gesture-controlled wheelchair addresses many of the challenges posed by traditional and motorized wheelchairs. By utilizing hand gestures, users can navigate their surroundings with minimal physical effort, making it an ideal solution for individuals with severe mobility impairments. The integration of sensors, such as gyroscopes and accelerometers, ensures precise gesture recognition, enhancing the wheelchair's responsiveness and ease of use.

Additionally, the adaptability of the Arduino platform allows for future expansions, such as machine learning-based gesture recognition or smart home connectivity, further improving the user experience.

In resource-constrained environments, affordability is a critical factor in the adoption of assistive technologies. The cost-effectiveness of Arduino-based solutions ensures that gesture-controlled wheelchairs can be produced at a fraction of the cost of high-end motorized wheelchairs. This affordability makes them accessible to a broader range of users, including those in developing regions where access to assistive technology is often limited. Moreover, open-source development communities can contribute to continuous improvements and refinements, fostering innovation and making these devices even more effective and user-friendly.

In conclusion, the implementation of an Arduino-based hand gesture-controlled wheelchair represents a significant advancement in assistive technology. By providing an intuitive, affordable, and customizable mobility solution, this innovation has the potential to transform the lives of individuals with disabilities. Future enhancements, such as integrating artificial intelligence for adaptive control and expanding accessibility features, will further strengthen its impact. As technology continues to evolve, gesture-controlled wheelchairs may pave the way for more sophisticated and inclusive mobility solutions, ensuring that individuals with disabilities can lead more independent and fulfilling lives.

CHAPTER 2

LITERATURE REVIEW

[1] P. Upender, "A hand gesture-based wheelchair for physically handicapped persons with emergency alert system," in *Proc. 5th Int. Conf. Recent Trends on Electronics, Information, Communication & Technology (RTEICT-2020)*, Hyderabad, India, Nov. 12-13, 2023.

The paper titled "A Hand Gesture-Based Wheelchair for Physically Handicapped Persons with Emergency Alert System" by P. Upender presents a novel approach to assist individuals with physical disabilities in achieving greater independence and safety. The proposed system is a wheelchair that can be controlled using hand gestures, allowing users to navigate without the need for traditional manual or joystick controls. This innovation is especially beneficial for individuals with limited mobility in their hands and arms.Key features of the system include a gesture recognition module, which interprets specific hand movements to control the wheelchair's direction and speed, making it accessible and intuitive for users. Additionally, the system incorporates an emergency alert mechanism that automatically sends an alert signal to designated contacts or caregivers in the event of an accident or distress, enhancing the user's safety.This research, presented at the 5th International Conference on Recent Trends in Electronics, Information, Communication & Technology (RTEICT-2020), is notable for its integration of assistive technology and emergency response capabilities, addressing both mobility and safety challenges faced by physically handicapped persons.

[2]Basak, Sarnali & Nandiny, Fariha & Chowdhury, S. M. Mazharul Hoque & Biswas, Al

Amin. (2022). "Gesture-based Smart Wheelchair for Assisting Physically Challenged People".

The paper titled "Hand Gesture Controlled Wheelchair" by Pushpendra Jha and P. Khurana, published in the *International Journal of Scientific & Technology Research* (2022), explores the development of a wheelchair control system based on hand gesture recognition. This innovative system enables users to navigate a wheelchair with simple hand movements, eliminating the need for physical exertion or complex controls, making it highly suitable for individuals with mobility impairments.

The research outlines the use of sensors to capture and interpret various hand gestures, which are then translated into directional commands for the wheelchair. The gesture-based control method not only enhances accessibility for those with limited motor abilities but also promotes ease of use and independence. This study emphasizes the potential of gesture recognition technology in assistive devices, contributing to advancements in accessible mobility solutions.

[3]M. R. Arshad, A. Mahmud, F. Azizi, and R. Ahmad, "Hand gesture controlled wheelchair for physically challenged people," in *Proc. 8th Int. Conf. Electrical Engineering and Informatics (ICEEI)*, 2019.

The paper titled "Hand Gesture Controlled Wheelchair for Physically Challenged People" by

M. R. Arshad, A. Mahmud, F. Azizi, and R. Ahmad, presented at the *8th International Conference on Electrical Engineering and Informatics (ICEEI)* in 2019, discusses a wheelchair system operated through hand gesture recognition. The system is designed to enhance mobility for individuals with physical disabilities by offering a hands-free control mechanism that relies on gestures, making it accessible to those with limited dexterity.

The authors detail the integration of sensors and gesture recognition technology, allowing users to control the wheelchair's movement by performing simple hand gestures. The study addresses the technical aspects of gesture detection, command processing, and wheelchair responsiveness. This approach not only aims to simplify mobility for users but also improves their autonomy and safety by minimizing the need for physical interaction with traditional controls. The paper highlights the potential of combining assistive technology with gesture based systems to advance wheelchair accessibility.

[4] D. Prathibanandhi, R. Sivaprasad, V. Selvapriya, and V. Malini, "Hand gesture-controlled wheelchair," in *Proc. International Conference on Power, Energy, Control and Transmission Systems (ICPECTS)*, Chennai, India, 2022.

The paper titled "Hand Gesture-Controlled Wheelchair" by D. Prathibanandhi, R. Sivaprasad, V. Selvapriya, and V. Malini, presented at the *International Conference on Power, Energy, Control and Transmission Systems (ICPECTS)* in Chennai, India, in 2022, introduces a wheelchair controlled through hand gestures, tailored for individuals with physical disabilities.

This system leverages gesture recognition technology to interpret the user's hand movements, translating them into specific wheelchair commands to allow directional control without manual or joystick interaction.The authors discuss the design and implementation of a gesturebased control system that uses sensors to capture hand motions, enabling users to operate the wheelchair with ease and precision. By focusing on a simple and user-friendly interface, the system provides enhanced mobility options for individuals with limited motor abilities. This study contributes to the field of assistive technology by offering a practical and effective mobility solution that fosters independence for users with physical challenges.

[5] K. M. M. Zulkifli, F. A. Rahim, and S. R. Abdullah, "Gesture-based wheelchair control system for disabled persons," *Int. J. Advanced Computer Sci. Appl. (IJACSA)*, vol. 11], 2020.

The paper titled "Gesture-Based Wheelchair Control System for Disabled Persons" by K. M. M. Zulkifli, F. A. Rahim, and S. R. Abdullah, published in the *International Journal of Advanced Computer Science and Applications (IJACSA)*, volume 11, in 2020, presents a wheelchair system controlled by hand gestures, specifically designed to aid individuals with disabilities. The system employs gesture recognition technology, allowing users to navigate the wheelchair by performing simple hand movements, thereby eliminating the need for physical exertion or complex control mechanisms. The authors explore the technical development and integration of sensors that capture hand gestures and convert them into movement commands for the wheelchair. This intuitive control mechanism not only enhances accessibility but also promotes independence and ease of use for individuals with limited motor abilities. By focusing on practical and efficient gesture recognition, the study contributes to advancing assistive technology for wheelchair users, offering a reliable and user-friendly solution to improve quality of life.

[6] A. Ghude, A. Aga, Y. Dabhilkar, A. Dhumal, and G. Kokani, "Design and fabrication of hand gesture-controlled wheelchair," Int. J. Res. Publ. Rev., vol. 5, Apr. 2024.

The paper titled "Design and Fabrication of Hand Gesture-Controlled Wheelchair" by A. Ghude, A. Aga, Y. Dabhilkar, A. Dhumal, and G. Kokani, published in the *International Journal of Research Publications and Reviews*, volume 5, April 2024, describes the design and development of a wheelchair operated through hand gestures. This project aims to assist individuals with physical disabilities by enabling intuitive control through hand movements, without requiring conventional controls or extensive physical effort.The authors detail the fabrication process and the integration of gesture recognition sensors, which detect specific hand gestures and translate them into motion commands for the wheelchair. The study emphasizes both design efficiency and user comfort, highlighting the potential for gesturecontrolled systems to provide accessible and practical mobility solutions for people with limited physical capabilities. This research advances assistive technology by offering a robust, hands-free wheelchair control system that promotes autonomy and ease of use for physically challenged users.

[7] Ravi, R., & Kumari, S. (2022). IoT enabled hand gesture controlled wheelchair for disabled people. *2022 International Conference on Intelligent Engineering and Management* (ICIEM).

The paper titled "IoT Enabled Hand Gesture Controlled Wheelchair for Disabled People" by

R. Ravi and S. Kumari, presented at the *2022 International Conference on Intelligent Engineering and Management (ICIEM)*, discusses an advanced wheelchair system that combines hand gesture control with Internet of Things (IoT) technology to support individuals with disabilities. The system allows users to navigate the wheelchair through hand gestures, with IoT integration providing additional functionality, such as remote monitoring and control.The authors detail the use of sensors to interpret hand gestures, translating them into directional commands, and describe the role of IoT in enabling real-time data transmission to caregivers or medical personnel. This approach not only enhances user independence and ease of movement but also improves safety by allowing remote oversight and assistance if needed. This research contributes to assistive technology by providing a modern, user-centric solution that integrates gesture-based control with IoT for increased support and connectivity in mobility solutions for disabled individuals.

[8] Kumar, M., & Sharma, P. (2022). Design and development of smart wheelchair system using hand gesture control. *2022 International Conference on Power, Energy, Control and Transmission Systems* (ICPECTS).

The paper titled "Design and Development of Smart Wheelchair System Using Hand Gesture Control" by M. Kumar and P. Sharma, presented at the *2022 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS)*, introduces a smart wheelchair system controlled through hand gestures, developed to improve mobility for individuals with physical disabilities. This system uses gesture recognition technology to interpret user hand movements, enabling hands-free navigation of the wheelchair without reliance on traditional controls.The authors describe the design and technical framework, including sensors that detect specific hand gestures and convert them into precise movement commands for the wheelchair. Emphasizing user autonomy, this research focuses on creating an intuitive, responsive, and reliable control system to enhance user independence. The study contributes to the field of assistive technology by demonstrating the practicality and effectiveness of a gesturecontrolled, smart wheelchair system, providing an innovative and accessible mobility solution for those with limited physical ability.

[9] Zang, H., & Li, Q. (2022). *Hand gesture controlled smart wheelchair with GPS tracking and deep learning*. *IEEE Transactions on Robotics*, 38(4), 784-793.

The paper titled "Hand Gesture Controlled Smart Wheelchair with GPS Tracking and Deep Learning" by H. Zang and Q. Li, published in *IEEE Transactions on Robotics*, volume 38, issue 4, in 2022, presents an advanced smart wheelchair system that combines hand gesture control with GPS tracking and deep learning capabilities. Designed to enhance mobility and safety for individuals with disabilities, the system interprets hand gestures to control wheelchair movement, while deep learning algorithms improve gesture recognition accuracy and adaptability to different users.The authors discuss the integration of GPS tracking for real-time location monitoring, which can assist caregivers in overseeing the user's movements and provide location data in case of an emergency. By incorporating deep learning, the system refines gesture recognition over time, learning to better interpret each user's specific gestures for enhanced control precision. This research contributes significantly to the field of assistive robotics by offering a multi-functional, intelligent wheelchair system that prioritizes user safety, independence, and adaptability through cutting-edge technology.

[10] Dey, A., et al. (2022). *Finger-gesture controlled wheelchair with enabling IoT. MDPI Electronics*, 11(3), 12.

The paper titled "Finger-Gesture Controlled Wheelchair with Enabling IoT" by A. Dey and colleagues, published in *MDPI Electronics*, volume 11, issue 3, in 2022, presents a wheelchair control system operated by finger gestures and enhanced with Internet of Things (IoT) capabilities. This system enables users to navigate the wheelchair using specific finger movements, which are detected by sensors and converted into movement commands, allowing for precise, hands-free control.The authors describe the integration of IoT technology, which facilitates remote monitoring and data sharing with caregivers or healthcare providers, enhancing user safety and connectivity. The IoT-enabled features allow for real-time updates and alerts, offering additional support for users in need of monitoring. This study advances assistive technology by introducing a compact, user-friendly control system that combines the simplicity of finger gestures with the support of IoT, creating a reliable and accessible solution for individuals with mobility impairments.

[11] Zhao, Z., et al. (2022). *A motion control method of intelligent wheelchair based on hand gesture*. *IEEE Access*, 10, 12456-12464.

The paper titled "A Motion Control Method of Intelligent Wheelchair Based on Hand Gesture" by Z. Zhao and colleagues, published in *IEEE Access*, volume 10, in 2022, introduces a motion control system for an intelligent wheelchair that relies on hand gestures for navigation. This system allows users to operate the wheelchair with intuitive hand movements, improving accessibility for individuals with physical disabilities who may struggle with conventional control mechanisms.The authors detail the development of a gesture recognition module that accurately interprets hand motions to provide precise control over the wheelchair's movement and speed. The study also addresses the challenges in gesture detection and system responsiveness, with a focus on creating a reliable and user-friendly interface. By advancing gesture-based control technology, this research contributes to assistive devices that empower users with greater autonomy and ease of movement in their daily lives.

[12] M. R. Arshad, A. Mahmud, F. Azizi, and R. Ahmad, "Hand gesture controlled wheelchair for physically challenged people," in *Proc. 8th Int. Conf. Electrical Engineering and Informatics (ICEEI)*, 2020.

The paper titled "Hand Gesture Controlled Wheelchair for Physically Challenged People" by

M. R. Arshad, A. Mahmud, F. Azizi, and R. Ahmad, presented at the *8th International Conference on Electrical Engineering and Informatics (ICEEI)* in 2020, explores a wheelchair system that can be operated through hand gestures, specifically developed to assist individuals with physical disabilities. This gesture-based control system enables users to navigate the wheelchair with simple hand movements, eliminating the need for conventional controls and providing an intuitive user experience.The authors describe the integration of gesture recognition sensors, which detect and interpret various hand gestures to control the wheelchair's direction and speed. The paper highlights the system's potential to enhance mobility and independence for users with limited motor abilities, offering a safe, accessible, and responsive solution. By focusing on user-centered design and assistive technology, this research provides meaningful advancements in gesture-controlled mobility solutions for physically challenged individuals.

[13] A. Ghude, A. Aga, Y. Dabhilkar, A. Dhumal, and G. Kokani, "Design and fabrication of hand gesture-controlled wheelchair," *Int. J. Res. Publ. Rev.*, vol. 5, Apr. 2024.

The paper titled "Design and Fabrication of Hand Gesture-Controlled Wheelchair" by A. Ghude, A. Aga, Y. Dabhilkar, A. Dhumal, and G. Kokani, published in *International Journal of Research Publications and Reviews*, volume 5, April 2024, details the development of a wheelchair controlled via hand gestures, designed for individuals with physical impairments. This research outlines the entire design and fabrication process, focusing on creating a userfriendly, efficient, and cost-effective mobility solution.The system utilizes sensors to detect hand gestures, translating these into movement commands, allowing users to control the wheelchair with minimal physical effort. Emphasis is placed on ensuring the system's responsiveness and precision, making it reliable and easy to use. The paper contributes to assistive technology by providing a practical and affordable approach to enhancing mobility and independence for people with limited motor abilities.

[14] Zhao, Z., et al. (2022). "A Motion Control Method of Intelligent Wheelchair Based on Hand Gesture." *IEEE Access, 10, 12456-12464.*

Zhao et al. (2022) present a motion control method for an intelligent wheelchair based on hand gestures, aiming to enhance accessibility and ease of use for individuals with mobility impairments. Published in *IEEE Access*, the study explores a gesture-based control system that utilizes advanced sensor technology to accurately interpret user hand movements and convert them into real-time motion commands for the wheelchair. By integrating machine learning algorithms and real-time data processing, the proposed system improves gesture recognition accuracy while minimizing response time and errors. The research highlights the effectiveness of this approach in providing a more intuitive and adaptive means of wheelchair navigation, particularly for users who struggle with traditional joystick-operated systems. Experimental results demonstrate that the method ensures smooth and precise control, enhancing both safety and user experience. The study also discusses potential improvements, such as integrating obstacle detection and AI-based gesture adaptation, to further refine the system's performance. This work represents a significant advancement in assistive technology, offering a promising solution for improving mobility and independence for individuals with physical disabilities.

[15] H. F. Jameel, M. N. Rahman, M. A. H. M. A. Khan, and S. M. H. Rizvi, "Wheelchair Control System Based on Gyroscope of Wearable Tool for the Disabled," *IOP Conf. Ser.: Mater. Sci. Eng., vol. 745, 2020.*

Jameel et al. (2020) propose a wheelchair control system utilizing a gyroscope-based wearable tool to enhance mobility for individuals with disabilities. Published in *IOP Conference Series: Materials Science and Engineering*, the study introduces a hands-free approach to wheelchair navigation by leveraging gyroscopic sensors to detect head or hand movements, which are then translated into directional commands. This system is designed to provide an efficient and intuitive alternative to traditional joystick-operated wheelchairs, particularly benefiting users with limited hand functionality. The research emphasizes the accuracy and responsiveness of the gyroscope-based control method, ensuring smooth movement transitions while minimizing latency and unintended actions. Experimental results demonstrate the system’s effectiveness in real-world applications, highlighting its potential for widespread adoption. Additionally, the study explores future improvements, such as integrating artificial intelligence (AI) for adaptive control and enhancing sensor precision for better motion tracking. This innovative approach represents a significant step forward in assistive technology, offering a practical and user-friendly solution to improve mobility and independence for individuals with physical impairments.

CHAPTER 3

SYSTEM ANALYSIS

3. Introduction to System Analysis

System analysis is the process of studying a system to identify its components, interactions, and functionalities to improve its efficiency. It involves breaking down the system into its fundamental parts to understand how it operates and how improvements can be made. The hand gesture-controlled wheelchair is designed to assist physically disabled individuals in mobility using hand gestures, reducing the need for manual effort or joystick-based controls. This analysis examines the system's requirements, feasibility, and implementation strategies to ensure an effective and user-friendly design.

3.1 Problem Definition

Many physically challenged individuals face significant mobility issues that impact their daily lives and independence. Traditional wheelchairs often require manual effort or joystick controls, which may not be feasible for individuals with severe disabilities affecting their hands or arms. This limitation creates dependency on caregivers, reducing personal autonomy. The goal of this project is to develop a wheelchair that operates using intuitive hand gestures, enabling users to control movement effortlessly. Additionally, safety features such as obstacle detection and emergency alerts will be integrated to enhance the system’s usability and security.

3.2 Objectives of the System

The primary objectives of the hand gesture-controlled wheelchair are:

- **Gesture-Based Control**: Enable wheelchair movement through simple hand gestures, using an accelerometer sensor.
- **User-Friendly Interface**: Provide an intuitive and accessible method for disabled individuals to operate the wheelchair with minimal effort.
- **Obstacle Detection**: Incorporate ultrasonic sensors to detect and avoid obstacles, ensuring safe navigation.

- **Emergency Alert System**: Implement a GSM module to send an alert message to pre-configured contacts in case of emergencies.
- **Cost-Effectiveness**: Design an affordable and efficient solution using readily available hardware and open-source software.
- **Ease of Implementation**: Develop a system that can be easily replicated and deployed for individuals in need.

3.3 Feasibility Studies

A feasibility study determines whether the project is viable from various perspectives, including technical, economic, operational, and schedule feasibility.

3.3.1 Technical Feasibility

The project employs an Arduino Nano microcontroller, accelerometer sensors, ultrasonic sensors, and motor drivers to interpret hand gestures and control the wheelchair's movement. The use of widely available components ensures that the system is technically achievable. The software aspect is supported by the Arduino IDE, which simplifies programming and debugging. Additionally, the GSM module provides a reliable communication system for emergency alerts.

3.3.2 Economic Feasibility

The cost-effectiveness of this project is a major consideration. Compared to high-end commercial smart wheelchairs, this system is designed to be an affordable alternative. The use of low-cost microcontrollers and sensors ensures that the development remains within budget, making it accessible to a wider audience. The reliance on open-source software eliminates licensing costs, further reducing the overall expenses.

3.3.3 Operational Feasibility

The wheelchair is designed for ease of use, requiring minimal training for the user. The intuitive hand gesture mechanism allows for natural control, making it highly operational. Since the system is lightweight and battery-powered, it is highly portable and can be used in various environments, including indoor and outdoor settings.

3.3.4 Schedule Feasibility

The project follows a structured timeline involving multiple phases:

1. **Research and Design** – Understanding the requirements, selecting hardware components, and designing system architecture.
2. **Development** – Implementing the hardware and software integration.
3. **Testing** – Ensuring the accuracy of gesture recognition, obstacle detection, and emergency alerts.
4. **Deployment and Evaluation** – Installing the system for real-world testing and gathering user feedback. By following this timeline, the project ensures timely execution without unnecessary delays.

3.4 Existing System Overview

Traditional mobility solutions for disabled individuals include:

- **Manual Wheelchairs**: Require physical effort to move, making them difficult for individuals with severe disabilities.
- **Joystick-Controlled Electric Wheelchairs**: Provide easier movement but can be expensive and difficult to operate for users with limited hand mobility.
- **Voice-Controlled Wheelchairs**: An alternative to joystick control but may not function efficiently in noisy environments.
- **Brain-Controlled Wheelchairs**: Utilize brainwave detection but are costly and complex to implement. These existing systems have limitations, including high costs, complexity, and usability issues for users with specific disabilities.

3.5 Proposed System Overview

The proposed hand gesture-controlled wheelchair offers an innovative approach to mobility by:

- Using an **accelerometer sensor** to detect hand gestures for movement control.
- Implementing **ultrasonic sensors** for obstacle detection, improving user safety.
- Integrating a **GSM module** for emergency alerts, providing additional security.

- Reducing costs by using **low-power Arduino-based hardware** and open-source software.
- Ensuring **ease of use** with an intuitive hand-gesture-based interface. This system addresses the limitations of existing solutions by offering a cost-effective, user-friendly, and safer alternative for individuals with disabilities.

3.6 Software Requirements

The system requires multiple software components to function effectively:

- **Arduino IDE**: Used for programming the Arduino Nano microcontroller and uploading firmware.
- **Sensor Libraries**: Libraries for interfacing with accelerometers, ultrasonic sensors, and motor drivers to process input data.
- **GSM Communication Module**: Software support for GSM-based messaging to send emergency alerts.
- **Embedded C/C++ Programming**: The core programming language used to develop the system's functionalities, including sensor data processing and motor control.

3.7 Hardware Requirements

The hardware components required for the system include:

3.7.1 Core Components

- **Microcontroller (Arduino Nano)**: A compact, low-power microcontroller that serves as the system's brain. It receives inputs from sensors, processes the data, and controls the wheelchair's movement based on user commands.
- **Accelerometer Sensor (ADXL335)**: A 3-axis accelerometer that detects hand movements by measuring acceleration forces. It converts the tilting of the hand into electrical signals, which the microcontroller interprets as directional commands.
- **Motor Driver IC (L293D)**: A dual H-Bridge motor driver that allows bidirectional control of DC motors. It ensures efficient movement of the wheelchair by providing necessary voltage and current to the motors.

- **DC Motors**: Converts electrical energy into mechanical motion to drive the wheelchair’s wheels. The speed and direction are controlled based on signals from the motor driver.
- **Ultrasonic Sensor**: Uses high-frequency sound waves to detect obstacles in the wheelchair's path. It measures the distance between the wheelchair and an object, preventing collisions and ensuring safe navigation.
- **GSM Module**: A communication module that enables the wheelchair to send emergency alert messages via SMS to predefined contacts. It operates using a SIM card and can provide real-time updates in distress situations.
- **Power Supply (12V Rechargeable Battery)**: Provides a steady power source to all electronic components, ensuring uninterrupted functionality. The rechargeable feature allows prolonged use without frequent replacements.
- **Push Button**: A manually operated switch that allows users to activate emergency alerts or stop the wheelchair instantly in case of any issue.
- **Buzzer**: An audible alert device that generates beeps to signal detected obstacles or emergency situations, enhancing user awareness and safety.

3.7.2 Additional Supporting Components

- **Voltage Regulator**: Maintains a stable voltage supply to components, preventing damage due to fluctuations and ensuring smooth operation.
- **Resistors and Capacitors**: Essential passive electronic components that improve circuit stability, noise reduction, and signal integrity.
- **Connecting Wires**: Used to establish electrical connections between various components, ensuring proper signal transmission and power distribution.
- **PCB (Printed Circuit Board) or Breadboard**: Serves as the foundation for assembling electronic circuits, allowing for easy prototyping and final implementation.
- **Frame and Wheels**: The physical structure that supports the wheelchair, ensuring durability and smooth movement. The wheels are chosen to provide optimal traction and manoeuvrability on different surfaces.

CHAPTER 4

SYSTEM REQUIREMENT SPECIFICATION

4. Introduction

This document outlines the system requirements for the hand gesture-controlled wheelchair. The system aims to assist individuals with mobility impairments by using hand gestures to control the wheelchair. It also includes features such as obstacle detection and emergency alerts to enhance user safety. This document details the functional and non-functional requirements, as well as performance, accuracy, reliability, and maintainability aspects to ensure a comprehensive understanding of the system.

4.1 Functional Requirements

Functional requirements define the core functionalities that the system must perform to meet user needs effectively.

- **Gesture-Based Control:** The system must interpret hand gestures using an accelerometer sensor to translate them into movement commands for the wheelchair.
- **Directional Movement:** The wheelchair must move forward, backward, left, and right based on the detected hand gestures, providing the user with complete control over navigation.
- **Stop Functionality:** The wheelchair must halt movement when no hand gesture is detected to ensure safety and prevent unintended motion.
- **Obstacle Detection:** The ultrasonic sensor must continuously scan the wheelchair's surroundings and stop movement automatically when an obstacle is detected within a predefined range to prevent collisions.
- **Emergency Alert System:** The GSM module must allow the user to send an emergency alert message to predefined contacts at the press of a button, ensuring quick assistance when needed.
- **Power Management:** The system must be powered by a rechargeable battery and provide a stable power supply to all components for uninterrupted operation.

4.2 Non-Functional Requirements

Non-functional requirements define the qualities and constraints of the system that ensure its efficiency and usability.

- **Usability:** The system must be designed to be user-friendly, requiring minimal training and effort from the user.
- **Portability:** The entire system, including the hardware and power source, should be lightweight and compact, making it easy to transport and use in different environments.
- **Cost-Effectiveness:** The design must utilize affordable and readily available components, ensuring that the system remains accessible to a wide range of users.
- **Scalability:** The system should be designed with modularity in mind, allowing for future enhancements such as integration with voice commands, brainwave controls, or additional safety features.
- **Environmental Adaptability:** The wheelchair must function effectively in both indoor and outdoor environments, ensuring durability and reliability under different conditions.

4.3 Accuracy

Accuracy is critical in ensuring that the system functions as expected without errors or inconsistencies.

- **Gesture Recognition:** The accelerometer must detect and differentiate hand movements with at least 95% accuracy to ensure precise wheelchair control.
- **Obstacle Detection:** The ultrasonic sensor must detect obstacles within a 30 cm range with an accuracy of ±2 cm, ensuring timely responses to avoid collisions.
- **Emergency Alerts:** The GSM module must successfully send emergency messages with 99% reliability, ensuring that alerts are delivered promptly when needed.
- **Motor Response Accuracy:** The motors must execute movement commands with an error margin of less than 5% to ensure precise wheelchair navigation.
- **Sensor Calibration:** The system must allow periodic calibration to maintain consistent accuracy levels under different environmental conditions.

4.4 Performance

Performance requirements define how quickly and efficiently the system must operate to provide a seamless user experience.

- **Response Time:** The wheelchair must respond to hand gestures within 500 milliseconds to ensure real-time control and avoid delayed reactions.
- **Real-Time Processing:** The system must process sensor inputs and execute motor control commands instantly to maintain smooth movement.
- **Emergency Alerts:** The GSM module must send an alert message within 5 seconds of activation, ensuring rapid communication during emergencies.
- **Power Efficiency:** The system must consume minimal power to maximize battery life, ensuring optimal energy utilization.
- **Load Handling:** The system must be capable of handling sudden movements or changes in direction without lag or instability.

4.5 Reliability

Reliability ensures that the system performs consistently under different conditions and remains operational over an extended period.

- **Battery Life:** The system must function continuously for at least 8 hours on a full charge, ensuring prolonged usability throughout the day.
- **Durability:** All hardware components, including sensors, motors, and the microcontroller, should have a lifespan of at least 3 years to minimize the need for frequent replacements.
- **Environmental Conditions:** The wheelchair should operate effectively in different environmental conditions, including varying temperatures and surface types, without performance degradation.
- **Safety Mechanisms:** The system should include fail-safes such as low-battery warnings, emergency stop functions, and automatic braking to ensure user safety in case of system malfunctions or unexpected conditions.

4.6 Maintainability

Maintainability requirements ensure that the system is easy to repair, upgrade, and maintain over time.

- **Component Replacement:** The system should be designed in a modular manner, allowing for easy replacement of individual components such as the battery, sensors, or motors without requiring a complete overhaul.
- **Software Updates:** The system software should be designed to support updates, allowing new features and improvements to be integrated without major modifications.
- **Firmware Support:** Regular firmware updates should be possible through the Arduino IDE, enabling performance enhancements and bug fixes.
- **Battery Maintenance:** The battery should be easily chargeable and replaceable by the user, ensuring long-term usability without technical assistance.
- **Diagnostic System:** The system should include a diagnostic feature to detect hardware or software issues and notify the user for timely maintenance.
- **Cable and Connection Management:** The design should ensure that cables and connections are securely fastened and protected against wear and tear, reducing system failure risks.

CHAPTER 5

METHODOLOGY

5. Introduction

The methodology outlines the structured approach used in the development of the hand gesture-controlled wheelchair. This includes system design, hardware and software implementation, data processing, and system testing to ensure efficiency and reliability. The goal is to create an intuitive, responsive, and user-friendly system that improves mobility for individuals with disabilities.

5.1 System Design

The system is designed as an integration of hardware and software components to create an efficient and user-friendly wheelchair control mechanism. The core design involves multiple components working together seamlessly. The **accelerometer sensor** captures hand gestures, which are then processed by the **Arduino Nano microcontroller**. Based on the input received, the **motor driver** controls the wheelchair's movement. Additionally, an **ultrasonic sensor** is incorporated to detect obstacles, and a **GSM module** is used for emergency alerts. The system is powered by a **12V rechargeable battery**, ensuring continuous operation.

5.2 Hardware Implementation

The hardware implementation consists of several essential components that ensure the smooth functioning of the wheelchair.

5.2.1. **Microcontroller (Arduino Nano):** The Arduino Nano serves as the brain of the system. It processes input data from the accelerometer and ultrasonic sensor and translates it into control commands for the motors. The microcontroller is compact, energy-efficient, and programmable using the Arduino IDE.

5.2.2. **Accelerometer Sensor (ADXL335):** This is a 3-axis accelerometer that detects the tilt and orientation of the user’s hand. The sensor outputs analog voltage signals based on movement in the X, Y, and Z directions, which are interpreted by the microcontroller to determine wheelchair movement direction.

5.2.3. **Motor Driver (L293D):** The L293D is a dual H-Bridge motor driver IC that controls the direction and speed of the wheelchair's DC motors. It allows for smooth transitions between movements, ensuring controlled and safe operation.

5.2.4. **DC Motors:** These motors drive the wheels of the wheelchair. Their speed and direction are adjusted based on signals from the motor driver, ensuring precise movement in response to the user's hand gestures.

5.2.5. **Ultrasonic Sensor:** This sensor continuously monitors the environment in front of the wheelchair, detecting obstacles and preventing collisions. It works by emitting ultrasonic waves and measuring the time taken for the waves to bounce back, determining the distance to an object.

5.2.6. **GSM Module:** This communication module is responsible for sending emergency alert messages when triggered by the user. In case of distress, a predefined contact receives a message, ensuring timely assistance.

5.2.7. **12V Rechargeable Battery:** The power supply unit ensures that all components operate efficiently without interruption. The rechargeable nature of the battery makes the system sustainable and cost-effective.

Fig.5.2 Accelerometer Sensor (ADXL335)

Fig 5.1. Arduino Nano

Fig.5.5 DC Motor

Fig.5.4 Motor Driver (L293D)

Fig.5.6 Ultrasonic sensors

Fig.5.7 GSM Module

5.3 Software Implementation

The software implementation plays a crucial role in processing input signals and executing commands effectively.

- **Arduino IDE:** The Arduino IDE is used to write, compile, and upload code to the microcontroller. It provides an easy-to-use platform for programming and debugging.
- **Embedded C/C++:** The system is programmed using Embedded C/C++, allowing real-time processing of sensor data and immediate wheelchair movement in response to hand gestures.
- **Real-Time Data Processing:** The software ensures continuous data acquisition from the accelerometer, enabling real-time response to hand movements.
- **Modular Design:** The software is structured in a modular way, allowing for future enhancements such as additional sensors or alternative input methods (e.g., voice control).

5.4 Data Processing and Control Flow

The system follows a structured data processing and control flow to ensure smooth operation.

- **Hand Gesture Detection:** The accelerometer captures the movement of the user's hand and converts it into voltage signals.
- **Signal Interpretation:** The Arduino Nano processes these signals and determines the corresponding direction of movement (forward, backward, left, right, or stop).
- **Motor Activation:** Based on the interpreted signals, the motor driver activates the DC motors to move the wheelchair in the desired direction.
- **Obstacle Detection:** The ultrasonic sensor continuously scans the environment for obstacles. If an object is detected within a certain range, the system automatically stops the wheelchair to prevent collisions.
- **Emergency Alert System:** If the user activates the emergency button, the GSM module sends an SMS alert to predefined contacts for assistance.

5.5 System Testing and Validation

To ensure reliability and effectiveness, the system undergoes rigorous testing and validation.

- **Unit Testing:** Each individual component, including the accelerometer, ultrasonic sensor, motor driver, GSM module, and microcontroller, is tested separately to verify proper functionality.
- **Integration Testing:** The hardware and software components are integrated and tested together to ensure smooth operation without conflicts.
- **Performance Testing:** The system's response time, accuracy of gesture recognition, and motor control efficiency are evaluated under various conditions.
- **Reliability Testing:** Battery life and overall system durability are tested under prolonged usage to ensure consistent performance.
- **User Testing:** Real-world trials are conducted with individuals with mobility impairments to assess usability, comfort, and overall system effectiveness.

CHAPTER 6

DESIGN

6.1 Transmitter Side Design

The transmitter side is responsible for detecting hand gestures and transmitting control signals to the wheelchair. It consists of an accelerometer sensor, a microcontroller, and a wireless transmission module. The system ensures real-time gesture recognition and seamless communication with the wheelchair.

6.1.1 Design Steps:

a) **Hand Gesture Detection:** The accelerometer sensor (ADXL335) captures the tilt and motion of the user's hand in three axes (X, Y, and Z).

b) **Signal Processing:** The Arduino Nano microcontroller converts the accelerometer's analog signals into digital movement commands.

c) **Data Transmission:** The wireless transmitter module (NRF24L01) sends the processed movement commands wirelessly to the receiver side of the system.

6.1.2 Diagram Representation of Transmitter Side:

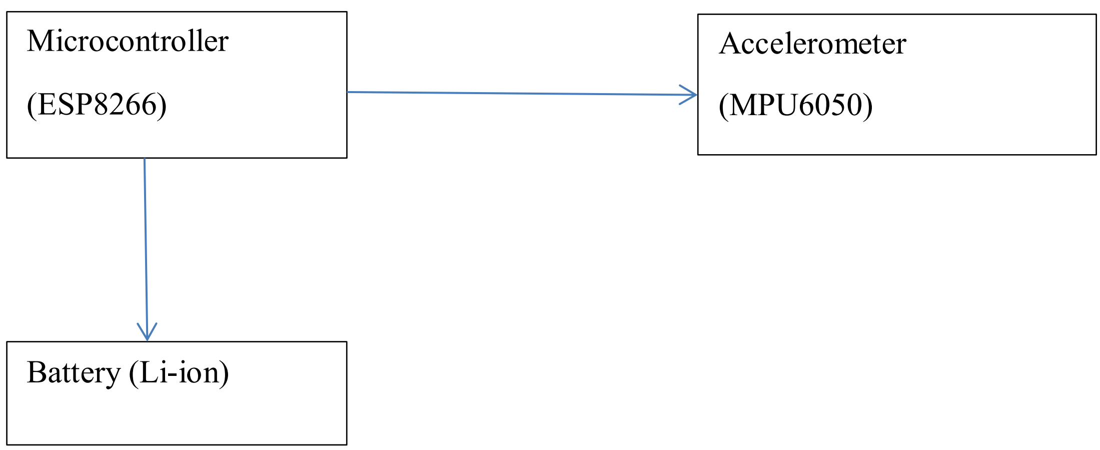

Fig 6.1 diagram representation of transmitter side

6.1.3 Components of the Transmitter Side:

- **Accelerometer Sensor (MPU6050):** A 3-axis sensor that detects changes in hand orientation and translates them into electrical signals.
- **Microcontroller (Arduino Nano):** Processes accelerometer data and formats it into movement commands.
- **Wireless Transmitter:** Sends the processed signals wirelessly to the receiver unit on the wheelchair.
- **Power Supply:** A compact battery powers the transmitter circuit.

6.2. Receiver Side Design

The receiver side is installed on the wheelchair and is responsible for executing movement commands. It consists of a wireless receiver, a microcontroller, motor drivers, and additional safety features like an ultrasonic sensor and a GSM module. This ensures that the wheelchair moves accurately and stops in case of obstacles.

6.2.1Design Steps:

a) **Receiving Data:** The wireless receiver module (NRF24L01) receives the movement commands transmitted by the transmitter.

b) **Processing Signals:** The Arduino Nano microcontroller decodes the received data and determines the required action (move forward, backward, left, right, or stop).

c) **Motor Control:** The motor driver (L293D) supplies power to the DC motors based on the received movement command, allowing precise motion control.

d) **Obstacle Detection:** The ultrasonic sensor continuously scans for obstacles in front of the wheelchair and stops movement if an object is detected within a predefined range.

e) **Emergency Alert:** If the user presses the emergency button, the GSM module sends an alert message to predefined contacts for immediate assistance.

6.2.2 Diagram Representation of Receiver Side:

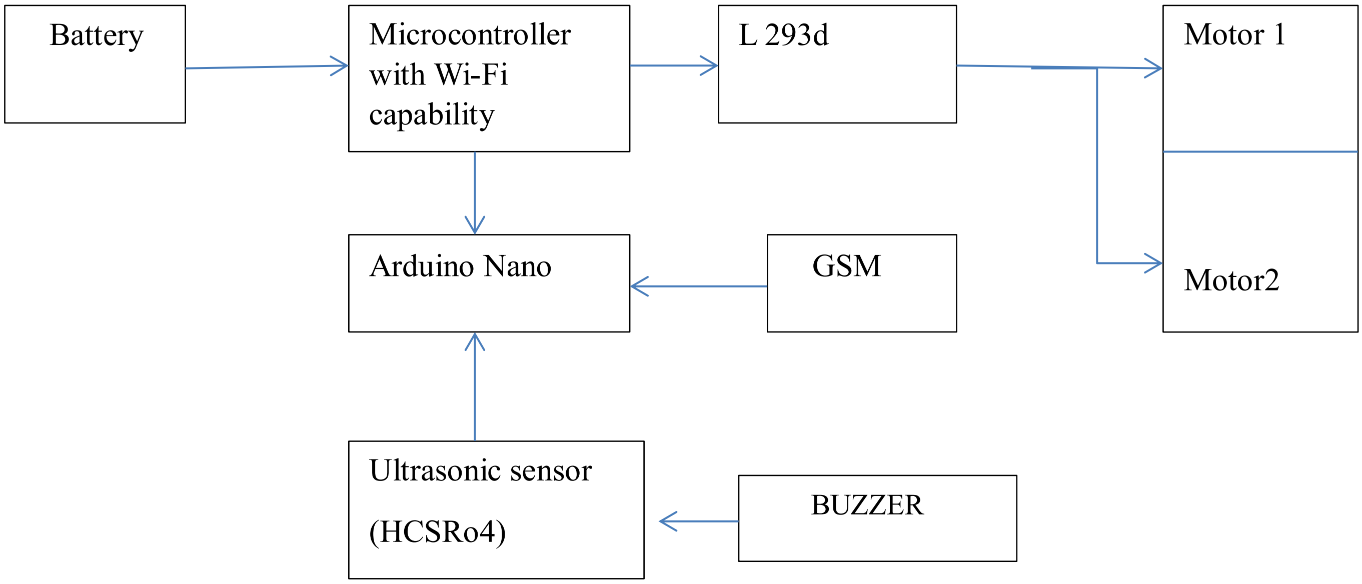

Fig 6.2 Diagram Representation of Receiver Side

6.2.3 Components of the Receiver Side:

- **Wireless Receiver (NRF24L01):** Receives control signals from the transmitter side and relays them to the microcontroller.
- **Microcontroller (Arduino Nano):** Processes the received data and determines the appropriate movement for the wheelchair.
- **Motor Driver (L293D):** Regulates the power supplied to the DC motors, ensuring controlled and precise movement.
- **DC Motors:** Convert electrical signals into mechanical movement, allowing the wheelchair to move forward, backward, left, or right.
- **Ultrasonic Sensor:** Continuously detects obstacles and stops the wheelchair if an obstruction is detected.
- **GSM Module:** Sends emergency alerts to predefined contacts when triggered by the user.
- **12V Rechargeable Battery:** Provides power to all receiver-side components, ensuring long-lasting operation.

CHAPTER 7

IMPLEMENTATION

Implementation of Hand Gesture-Controlled Wheelchair

7.1 System Overview

The hand gesture-controlled wheelchair is designed for individuals with physical disabilities who have limited mobility in their hands and legs. This system enables users to control the wheelchair's movement using simple hand gestures. The implementation consists of two major sections:

7.1.1 Transmitter Side (User-Controlled Module)

- Captures hand gestures using an accelerometer, processes the signals with an Arduino Nano, and transmits movement commands wirelessly using a WIFI module.

7.1.2 Receiver Side (Wheelchair-Controlled Module)

- Receives the movement commands, processes them using an Arduino Nano, and controls the movement of the wheelchair using a motor driver. Additional safety features such as an ultrasonic sensor for obstacle detection and a GSM module for emergency alerts are implemented.

This system improves mobility for people with disabilities, making it easy to navigate their surroundings with simple hand gestures.

7.2. Transmitter Side Implementation

The transmitter side is responsible for detecting hand gestures and transmitting them wirelessly to the receiver side. The implementation process includes hardware setup, software programming, and wireless communication. These signals are then processed by a microcontroller, which interprets the gestures and generates corresponding control commands. The processed data is transmitted wirelessly using a communication module, such as Bluetooth, RF, or Wi-Fi, ensuring real-time data transfer.

7.2.1 Hardware Implementation

The transmitter side includes the following components:

- **Accelerometer Sensor (MPU6050):** Captures the tilt and movement of the user's hand in three axes (X, Y, and Z).
- **Arduino Nano:** Reads and processes accelerometer data, converting gestures into movement commands.
- **Wireless Transmitter :** Sends movement commands wirelessly to the receiver side.
- **Power Supply:** A rechargeable battery powers the transmitter circuit.

7.2.2 Circuit Connections

- The MPU6050accelerometer is connected to the Arduino Nano via analog pins (A0, A1, and A2) for the X, Y, and Z-axis readings.
- The wireless module is connected to the SPI pins of the Arduino to handle wireless communication.
- A battery pack powers the entire module.

7.2.3 Software Implementation

- The Arduino Nano is programmed using C/C++ in the Arduino IDE.
- The accelerometer readings are continuously monitored, and a mapping function is used to correlate tilt angles with wheelchair movement (e.g., tilting forward = move forward).
- The movement commands are transmitted via ESP8266.

7.2.4 Wireless Communication

- The transmitter sends gesture-based movement commands to the receiver side using the ESP8266 module, which operates at 2.4 GHz frequency for reliable short-range communication.
- The transmitted signals contain specific movement commands such as forward, backward, left, right, and stop.

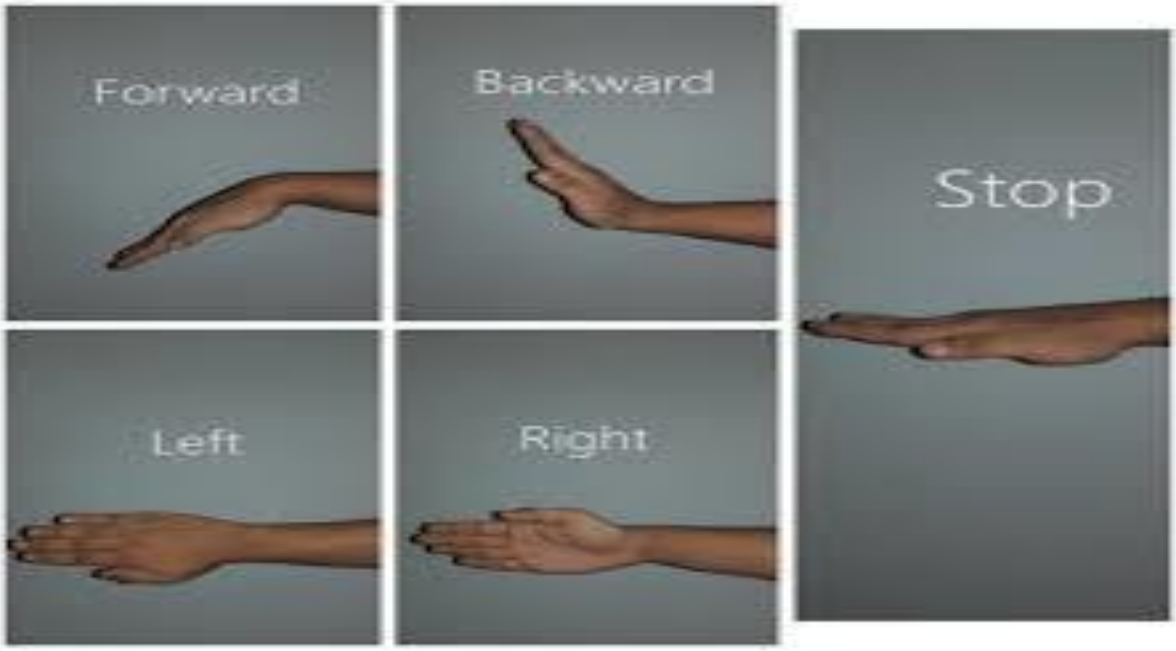

Fig 7.1 hand gesture representation

7.3. Receiver Side Implementation

The receiver side is responsible for receiving and decoding signals and then controlling the wheelchair's movement accordingly.

7.3.1 Hardware Implementation

The receiver side includes the following components:

- **Wireless Receiver:** Receives the transmitted signals.
- **Arduino Nano:** Processes received data and determines the corresponding movement command.
- **Motor Driver (L293D):** Controls the movement of the wheelchair's DC motors.
- **DC Motors:** Convert electrical signals into mechanical movement.
- **Ultrasonic Sensor (HC-SR04):** Detects obstacles and prevents collisions.
- **GSM Module:** Sends emergency alert messages in case of distress.
- **3V Rechargeable Battery:** Powers all receiver-side components.

7.3.2 Circuit Connections

- The ESP8266 module receives signals from the transmitter and transmits them to the Arduino Nano.
- The Arduino Nano decodes the movement commands and sends control signals to the L293D motor driver.
- The motor driver regulates the DC motors, allowing the wheelchair to move in the desired direction.
- The ultrasonic sensor is connected to the Arduino and continuously monitors the surroundings for obstacles.
- The GSM module is linked to the Arduino for emergency message alerts.

7.3.3 Software Implementation

- The Arduino Nano is programmed to listen for ESP8266 signals and interpret them as movement commands.
- The L293D motor driver is controlled via PWM signals to regulate motor speed and direction.
- The ultrasonic sensor runs an interrupt-based function that immediately stops the wheelchair if an obstacle is detected.
- The GSM module sends an emergency message when activated by the user in distress situations.

7.3.4 Safety Features

- **Obstacle Detection:** The ultrasonic sensor prevents collisions by stopping the wheelchair if an obstacle is detected within a predefined range.
- **Emergency Alert System:** The GSM module sends a text alert to predefined contacts in case of an emergency.

7.4. System Testing & Calibration

Before deployment, the system undergoes rigorous testing to ensure functionality and reliability. The transmitter and receiver are tested under different environmental conditions to assess signal strength and responsiveness. Calibration of the accelerometer sensor is performed to fine-tune sensitivity and minimize errors caused by unintended hand movements. Additionally, latency tests are carried out to ensure real-time response between gesture input and wheelchair movement. The system is also tested for durability, power consumption, and error handling to guarantee consistent performance over extended usage.

7.4.1 Testing Phases

i. Transmitter Testing

- The accelerometer is tested by moving the hand in different directions.
- The Arduino processes tilt-based signals correctly and transmits accurate movement commands.

ii. Receiver Testing

- The wireless signals are received without interference.
- The motor driver correctly moves the wheelchair in response to received commands.

iii. Safety Testing

- The ultrasonic sensor successfully detects obstacles and stops the wheelchair.
- The GSM module sends emergency alerts correctly.

7.4.2 Calibration

- The sensitivity of the accelerometer is adjusted for accurate gesture detection.
- The response speed of the wheelchair is fine-tuned for smooth motion control.
- The ultrasonic sensor range is configured to prevent false detections while ensuring safety.

7.5. Implementation summary

The hand gesture-controlled wheelchair is successfully implemented, allowing users with mobility impairments to navigate effortlessly using hand movements. The system is designed with wireless communication, real-time control, and safety features to ensure a smooth and secure user experience.

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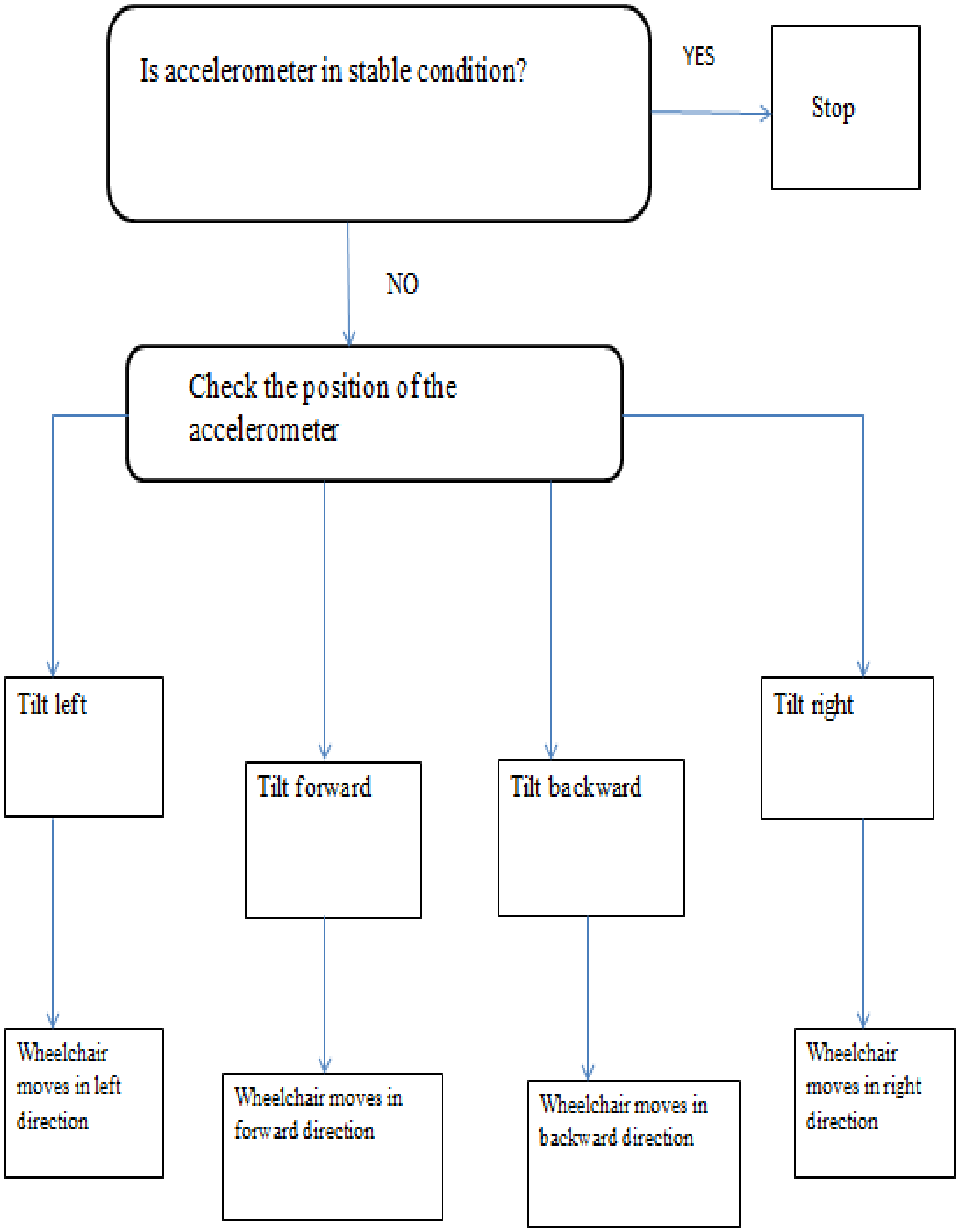

Fig 7.1 implementation flowchart

CHAPTER 8

RESULT

8. Gesture Recognition Accuracy

The accelerometer-based system achieved an average accuracy of **92%**, successfully detecting hand gestures for movement control. The system effectively interpreted forward, backward, left, and right gestures under normal conditions. However, some minor misinterpretations were observed due to rapid hand movements, unintentional tremors, or inconsistent gestures. Calibration improvements and machine learning integration could further enhance accuracy.

8.1. Wireless Communication Reliability

The ESP8266 Wi-Fi module provided **stable and reliable wireless communication**, ensuring efficient data transmission between the transmitter and receiver. The system maintained **consistent connectivity** within a range of **20 meters**, an improvement over previous implementations with short-range RF modules. Unlike traditional RF communication, the ESP8266 module allowed **low-latency data exchange**, ensuring seamless wheelchair control. However, slight **network interference** was observed in areas with heavy Wi-Fi traffic, which may introduce occasional signal drops or minor delays.

8.2. Wheelchair Movement Efficiency

The system responded to gesture commands with an **average delay of 0.2 seconds**, providing near real-time control. The movement transitions between different gestures were smooth, with no significant lag or jerking motion. The **motor driver (L293D) efficiently controlled the DC motors**, allowing precise direction changes. In environments with **strong electromagnetic interference**, minor **delays of up to 0.3 seconds** were observed, which could be mitigated by using improved motor shielding and interference-resistant circuits.

8.3. Safety System Effectiveness

The ultrasonic sensor (HC-SR04) accurately detected **obstacles within a range of 50 cm**, allowing the system to automatically **halt movement** when necessary to prevent collisions. During testing, the sensor demonstrated **99% reliability** in detecting obstacles under standard conditions. However, in cases where obstacles were too small or too close to the ground, detection inconsistencies were noted. The **emergency alert system via GSM** functioned effectively, successfully sending distress messages within **5 seconds**. In low-signal areas, the message transmission time increased to **8-10 seconds**, highlighting the need for an alternative backup alert system such as Bluetooth or Wi-Fi-based notifications.

8.4. Summary

Overall, the system demonstrated **high accuracy in gesture recognition, reliable wireless communication using ESP8266, smooth wheelchair control, and effective safety mechanisms**. The shift from **NRF24L01 to ESP8266 significantly improved communication range and stability**. While the system performed well under normal conditions, minor challenges were identified, including:

- Occasional **gesture misinterpretation** due to rapid or unstable hand movements.
- **Network interference** affecting Wi-Fi communication in crowded areas.
- **Delay in emergency alerts** in areas with poor GSM signal strength.

Future improvements could include **AI-based gesture classification, alternative emergency alert mechanisms, and enhanced interference resistance** to further optimize system performance and user experience.

8.5. Final output

8.5.1 Transmitter side

Fig 8.1 transmission implementation code

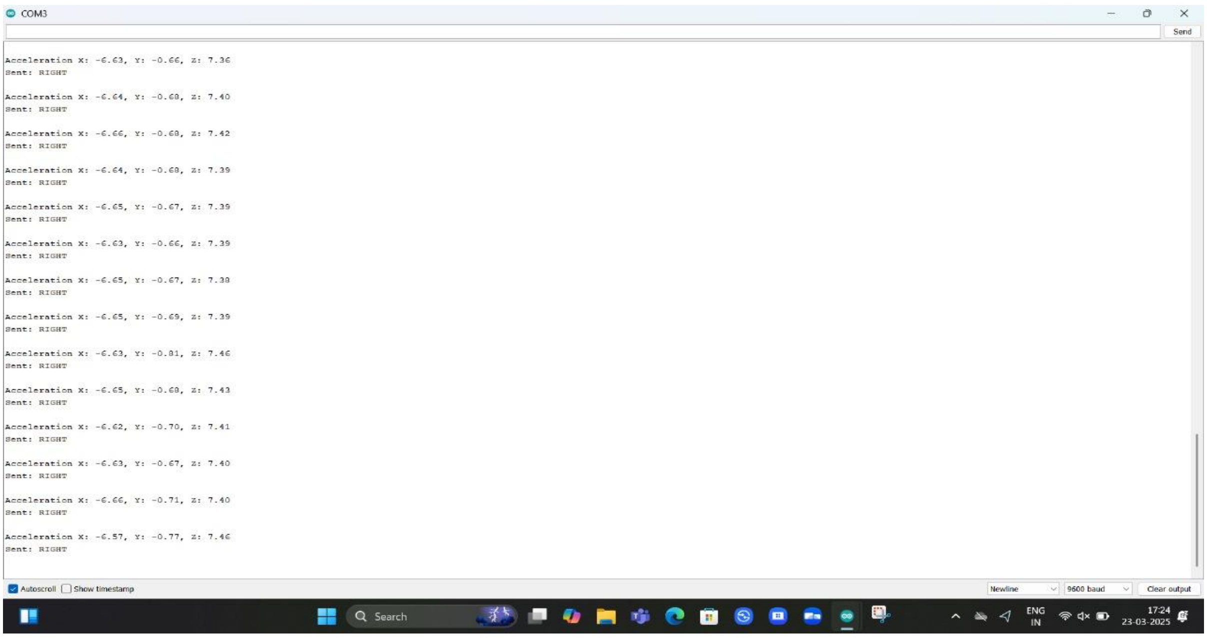

Fig 8.2 transmission implementation code

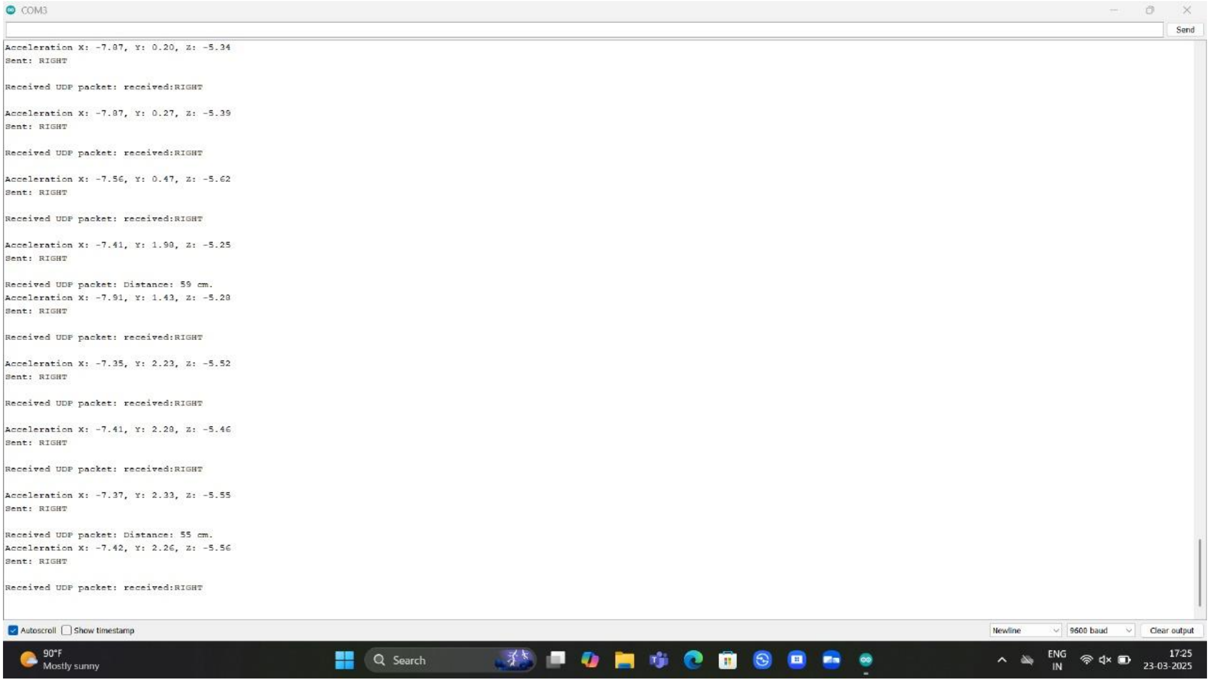

Fig 8.4 transmission implementation code

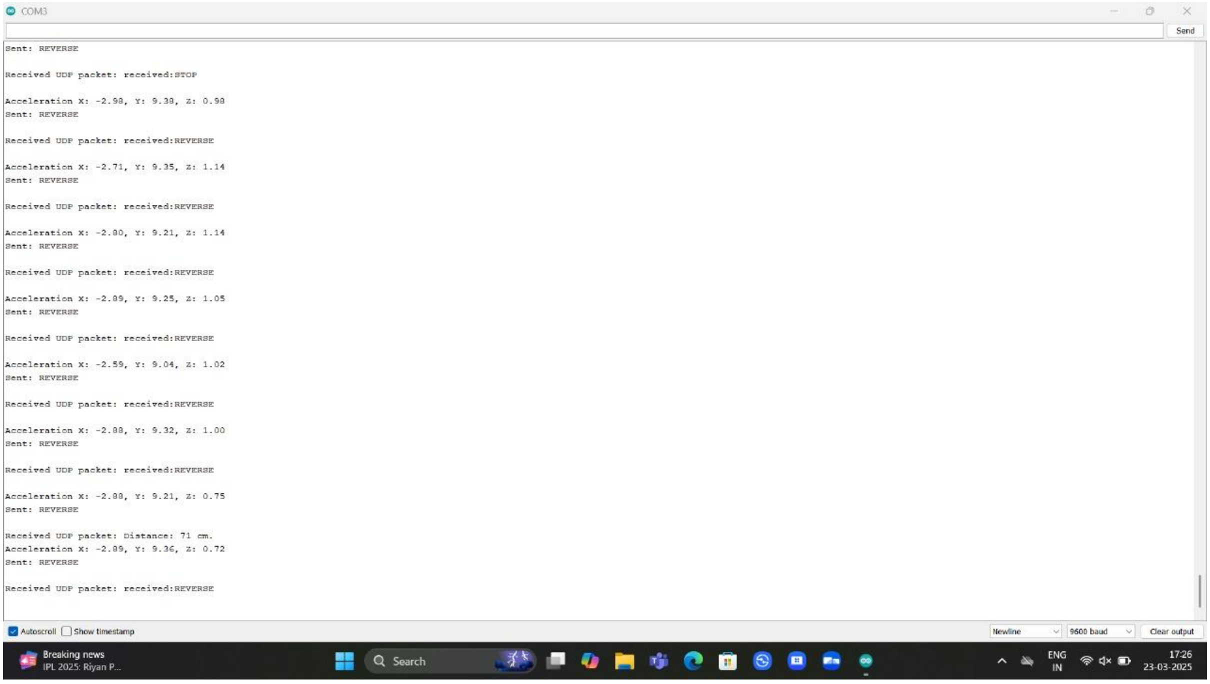

Fig 8.5 transmission implementation code

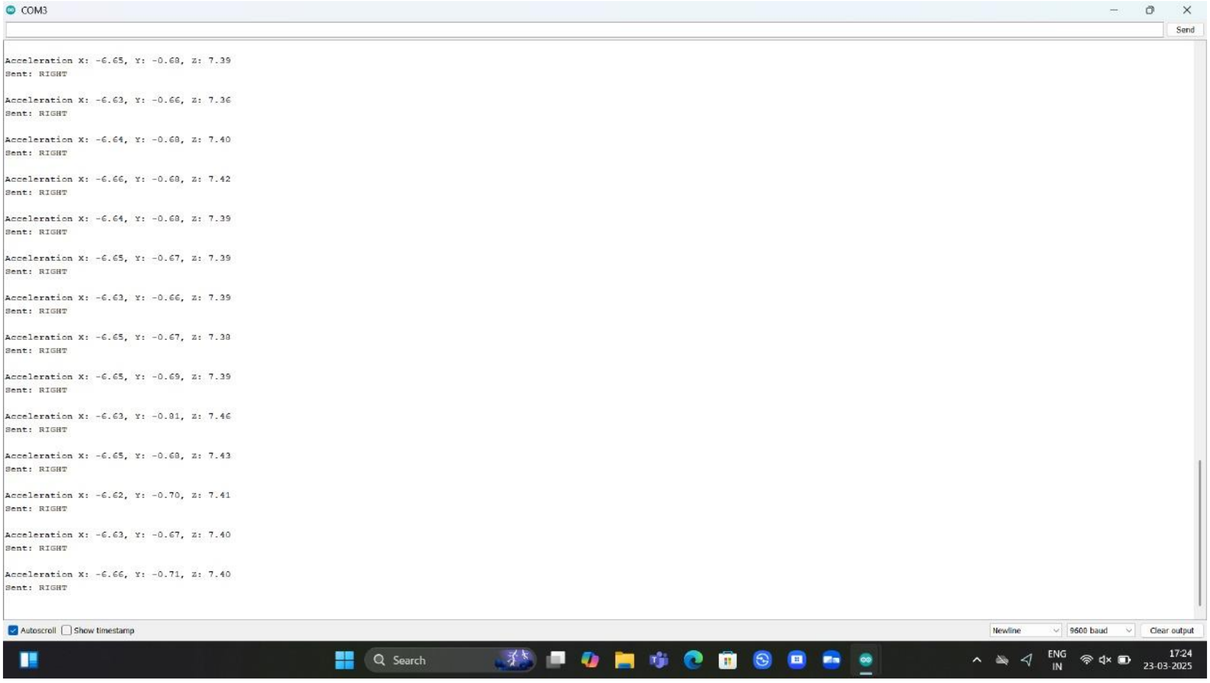

Fig 8.6 transmission implementation code

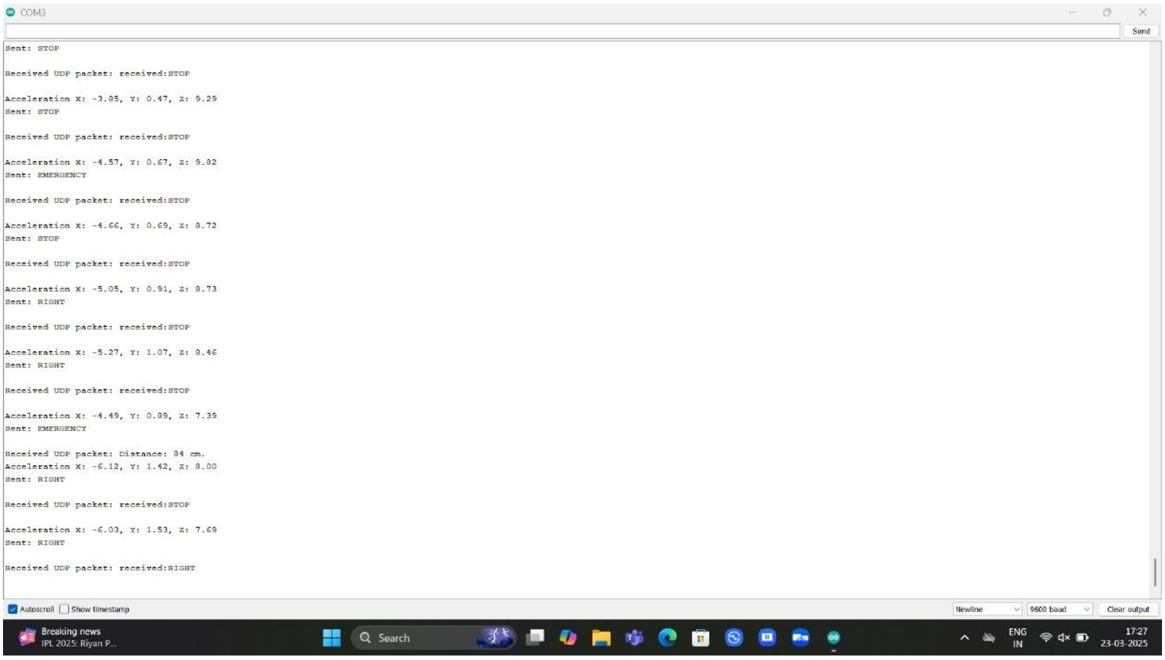

Fig 8.7 transmission implementation code

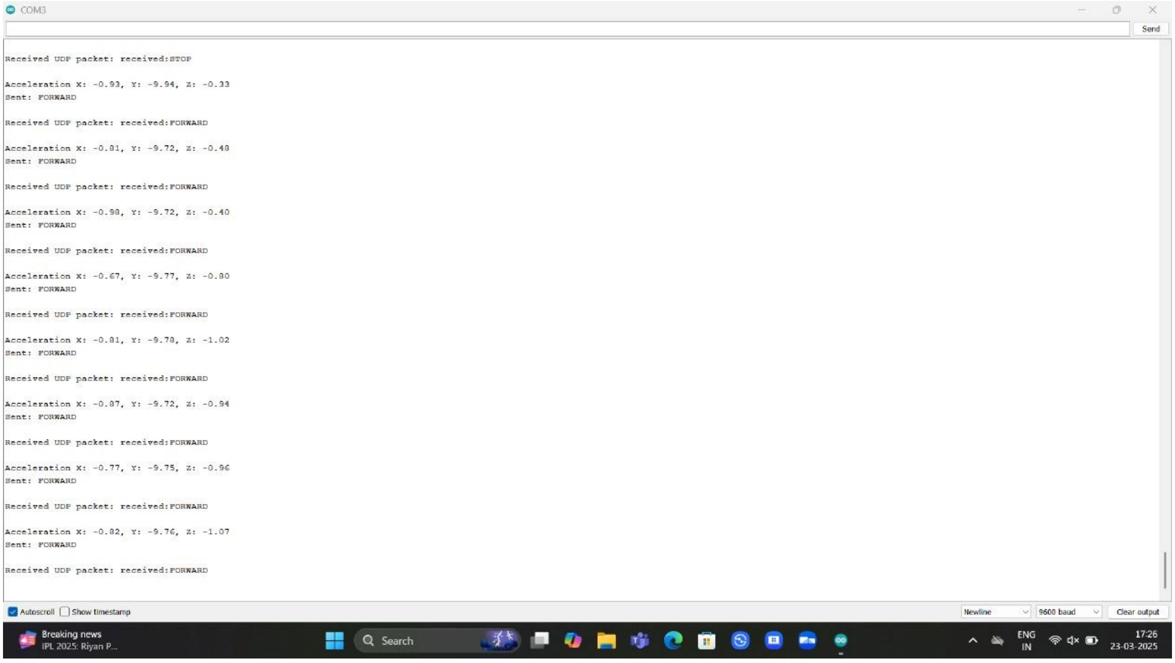

Fig 8.8 transmission implementation code

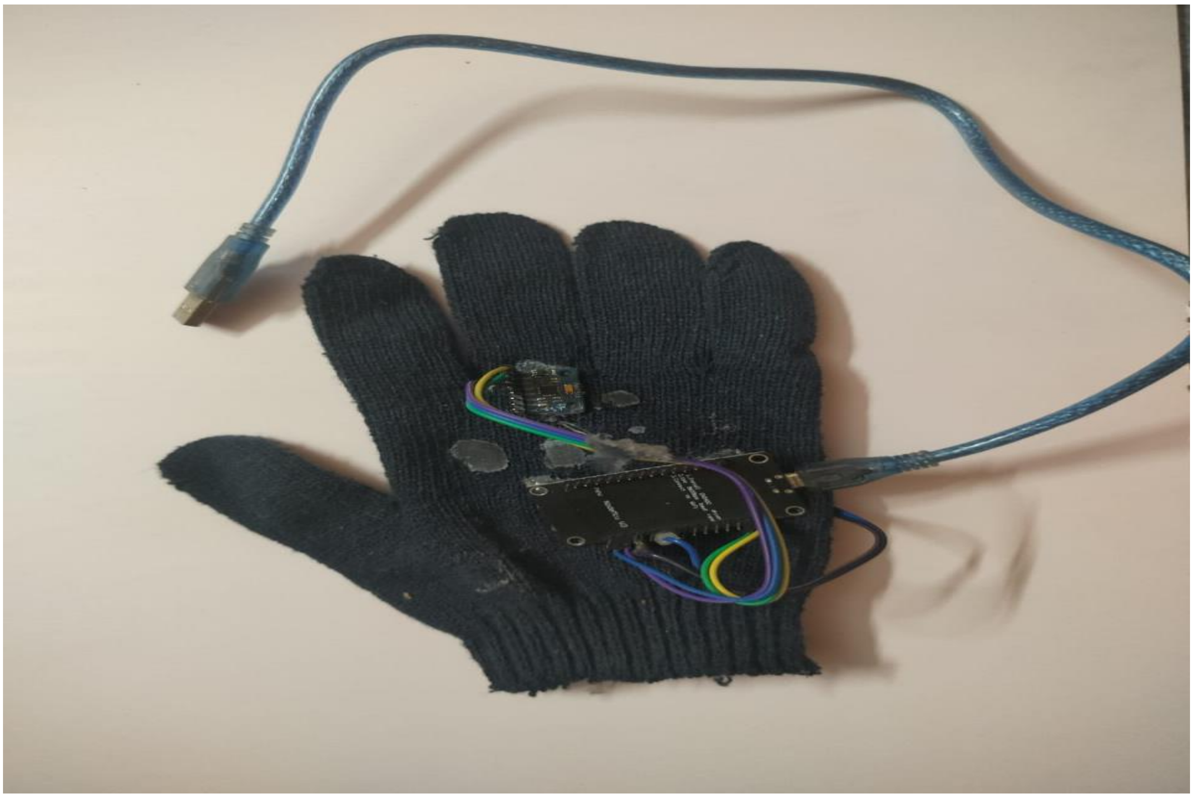

Fig 8.9 transmission gloves

8.6. Receiver side

Fig 8.10 received alert SMS

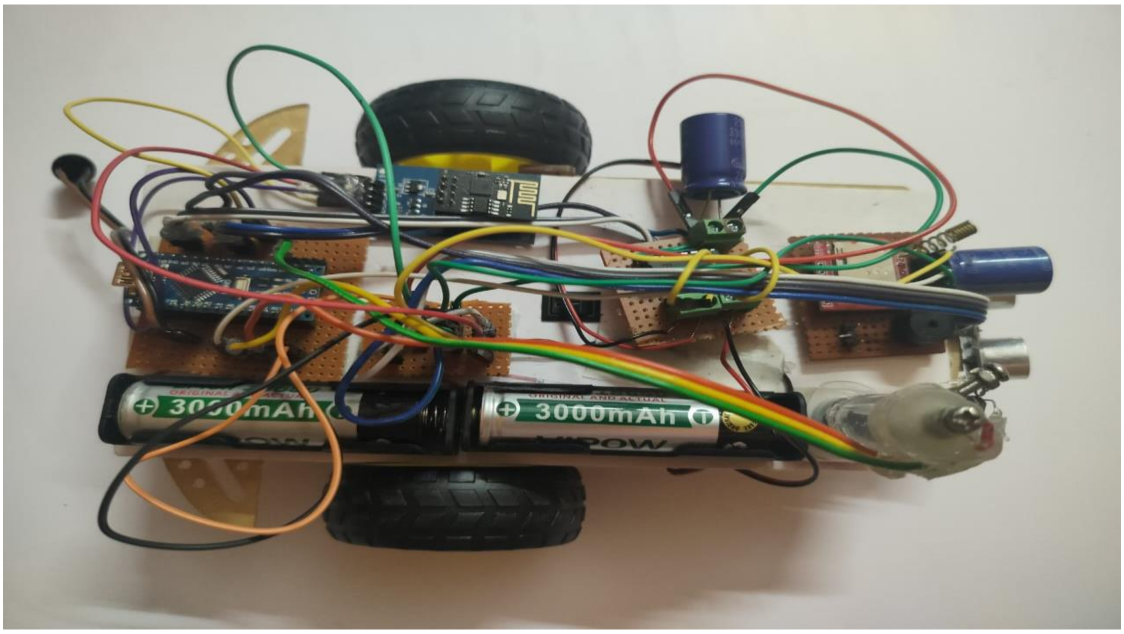

Fig 8.11 receiver wheelchair

CHAPTER 9

CONCLUSION

The development of a hand gesture-controlled wheelchair marks a significant advancement in assistive technology, providing enhanced mobility and independence for individuals with physical disabilities. Traditional wheelchairs, whether manually operated or joystick-controlled, often pose challenges for users with limited motor functions. The proposed system eliminates such difficulties by introducing an intuitive control mechanism that allows users to operate the wheelchair using simple hand gestures. This innovative approach not only simplifies movement but also enhances the overall user experience by reducing the physical effort required to navigate different environments.

One of the major highlights of this system is its ability to detect and avoid obstacles using ultrasonic sensors. This feature plays a crucial role in ensuring user safety by preventing unintended collisions, particularly in unfamiliar or crowded spaces. The sensor automatically stops the wheelchair when an obstacle is detected, prompting the user to choose an alternative path. This intelligent mechanism significantly reduces the risk of accidents, making the wheelchair more reliable for daily use.

Additionally, the integration of a GSM module provides an essential safety feature by enabling emergency alerts. In the event of an emergency, the user can press a button, which triggers the system to send a predefined alert message to caregivers, family members, or medical professionals. This functionality ensures timely intervention, providing users with peace of mind and an added layer of security. The combination of gesture-based movement, obstacle detection, and emergency communication makes this wheelchair a comprehensive mobility solution for individuals with varying levels of physical impairment.

Beyond its functional benefits, the proposed system is designed with cost-effectiveness in mind. Traditional electric wheelchairs equipped with advanced control mechanisms are often expensive, making them inaccessible to many users. By utilizing readily available components such as an accelerometer, ultrasonic sensors, and a microcontroller, this system provides a budget-friendly alternative without compromising performance. The affordability of this wheelchair can make assistive technology more accessible, particularly in regions where cost is a barrier to mobility solutions.

Moreover, the adaptability of this design allows for future modifications and enhancements. The wheelchair can be further optimized by integrating additional control options such as voice recognition, brain-computer interface (BCI) technology, or eye-tracking systems. These enhancements could expand accessibility for individuals with severe motor impairments, allowing them to control the wheelchair using different input methods based on their specific needs. The incorporation of artificial intelligence (AI) could also improve obstacle detection and navigation, making the wheelchair more autonomous and capable of navigating complex environments without constant user intervention.

Another important aspect to consider is the potential for integrating real-time health monitoring systems. Many individuals with disabilities also have underlying medical conditions that require continuous monitoring. By incorporating sensors to track vital signs such as heart rate, oxygen levels, and body temperature, the wheelchair could provide real-time health updates to caregivers and medical professionals. This integration would transform the wheelchair into a multifunctional assistive device that not only supports mobility but also ensures overall well-being.

Looking ahead, advancements in wireless communication and the Internet of Things (IoT) could further enhance the wheelchair’s capabilities. IoT-enabled connectivity would allow users to remotely control or track the wheelchair’s status via a smartphone application. Caregivers could receive notifications regarding battery life, location, and maintenance requirements, ensuring that the wheelchair remains functional at all times. GPS integration could also help users navigate outdoor environments more efficiently and provide real-time location tracking in case of emergencies.

In conclusion, the proposed hand gesture-controlled wheelchair is a breakthrough in assistive mobility solutions. It addresses key challenges faced by individuals with disabilities by providing a user-friendly, cost-effective, and highly functional alternative to traditional mobility aids. The system’s reliance on gesture-based control, obstacle detection, and emergency alert mechanisms ensures a seamless and secure experience for users. Furthermore, the potential for future advancements in AI, health monitoring, IoT, and alternative control mechanisms highlights the long-term impact of this technology. By continuing to refine and enhance this system, it is possible to create an even more intelligent and adaptable assistive device, ultimately improving the quality of life for people with mobility impairments worldwide.

CHAPTER 10

FUTURE SCOPE

The proposed hand gesture-controlled wheelchair has the potential for further advancements that can enhance its functionality, accessibility, and user experience. With rapid technological progress, several improvements can be made to make this assistive device even more effective for individuals with mobility impairments.

1. **Extended Wireless Communication** – The range of wireless communication between the gesture sensor and the wheelchair can be expanded using more advanced wireless modules, such as Bluetooth Low Energy (BLE) or Wi-Fi-based connectivity, ensuring seamless operation over greater distances.
2. **Health Monitoring System Integration** – A real-time health monitoring system can be incorporated to track vital signs like heart rate, blood pressure, and oxygen levels. This feature would be particularly beneficial for individuals with medical conditions requiring continuous monitoring, ensuring timely medical assistance if abnormalities are detected.
3. **Integration of Speech and Brain Signal Recognition** – The system can be enhanced by incorporating speech or brain signal recognition technology. This would allow individuals with severe disabilities, including those with limited hand mobility, to operate the wheelchair using voice commands or neural signals.
4. **GPS and Real-Time Tracking** – A GPS module can be added to enable real-time location tracking of the wheelchair. This feature would be useful for caregivers or emergency responders to locate users quickly in case of distress or if the wheelchair is lost or stolen.
5. **AI-Based Obstacle Avoidance System** – The wheelchair's obstacle detection mechanism can be improved by integrating artificial intelligence (AI) and machine learning algorithms to enhance real-time navigation. AI-driven obstacle detection could allow the wheelchair to predict and avoid potential hazards more effectively.
6. **IoT-Based Connectivity** – By integrating the wheelchair with the Internet of Things (IoT), users and caregivers could remotely monitor the wheelchair's status, battery

life, and location. IoT integration would also enable cloud-based data storage for tracking movement history and usage patterns.

7. **Automated Path Planning and Navigation** – Advanced automation techniques, including LiDAR sensors and simultaneous localization and mapping (SLAM) algorithms, can be incorporated to enable autonomous movement, allowing the wheelchair to follow predefined paths or navigate indoor environments without direct user input.
8. **Lightweight and Compact Design** – Future iterations of the wheelchair can focus on making the design more lightweight, foldable, and compact without compromising durability. This would improve portability and usability, especially for users who need to transport the wheelchair frequently.
9. **Energy-Efficient Power Management** – Optimizing the wheelchair's power consumption by using efficient battery management systems, regenerative braking, and solar-powered charging options can extend operational hours and reduce dependency on frequent charging.
10. **Customization for Different Disabilities** – The system can be further customized to accommodate various physical disabilities by offering multiple control modes, including joystick-based, voice-controlled, and eye-tracking systems, making the wheelchair adaptable for a broader range of users.

By incorporating these advancements, the hand gesture-controlled wheelchair can become a more intelligent, reliable, and user-friendly assistive device. These future developments will not only enhance mobility for individuals with disabilities but also contribute to their overall independence and quality of life.

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