IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, April 2025
Impact Factor: 7.67

Design and Implementation of Hand Gesture Controlled Wheelchair for Physically Challenged People

Prof J.S. Edle, Siddhant R Chakre, Vedant P Khadse, Vaibhav B Hiwarale, Vinay C Wankhade
Professor, Department of Electronics & Telecommunication Engineering
Students, Department of Electronics & Telecommunication Engineering
SIPNA College of Engineering and Technology, Amravati, Maharashtra, India

Abstract: *Mobility issues can greatly impact the autonomy and overall well-being of people with disabilities. Traditional wheelchair control systems, such as manual or joystick-based methods, often demand substantial physical effort or fine motor control, making them unsuitable for individuals with severe impairments. This research introduces a hand gesture-controlled wheelchair using an accelerometer-based motion detection system to interpret hand gestures for directional control. The system combines Micro-Electro-Mechanical Systems (MEMS) sensors, embedded hardware, and wireless modules to ensure accurate and efficient operation. Leveraging real-time signal processing and rapid gesture recognition, the wheelchair achieves reliable and precise control while minimizing false detections and environmental disturbances. Experimental validation confirms the system's accuracy, robustness, and ease of use, offering an affordable and practical mobility solution for physically challenged individuals.*

Keywords: Hand Gesture-Controlled Navigation, Smart Wheelchair, MEMS Sensors, Human-Machine Interaction

I. INTRODUCTION

Individuals with mobility impairments face significant barriers to independence and everyday activities. The World Health Organization estimates that close to one billion individuals around the world depend on some form of mobility aid. Traditional wheelchairs, whether manually operated or joystick-controlled, require significant physical effort or dexterity, which can be a major obstacle for those with conditions such as paralysis or muscular dystrophy. Recent innovations in human-machine interaction and embedded technology have facilitated the creation of gesture-based wheelchairs, which offer a touch-free, intuitive control method.

Over time, wheelchair designs have evolved from simple manual models to advanced electric variants. Smart wheelchairs now incorporate sensors, machine learning, and Internet of Things (IoT) capabilities. Among emerging control methods, gesture recognition stands out due to its simplicity, responsiveness, and low cognitive demand. Despite this, many existing gesture-controlled systems still face drawbacks such as low detection accuracy, high costs, environmental constraints, and limited adaptability to user diversity.

Hand gesture recognition, a domain within human-machine interaction (HMI), utilizes MEMS sensors such as accelerometers and gyroscopes to interpret movement-based inputs. These signals are processed via embedded systems like Arduino or Raspberry Pi, which translate specific gestures into motion commands. Compared to voice-controlled systems that struggle with noise or speech issues, gesture-based systems offer greater reliability. Likewise, unlike Brain-Computer Interfaces (BCIs), which are complex and expensive, gesture-controlled systems provide a more accessible and non-invasive alternative.

While advancements have been achieved, significant challenges still exist, particularly in enhancing the accuracy, responsiveness, and adaptability of these systems. This research proposes a real-time, hand gesture-controlled wheelchair system utilizing high-precision MEMS sensors, efficient signal processing, and wireless communication to

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 5, Issue 8, April 2025 Impact Factor: 7.67

address these challenges. The system's performance is evaluated in terms of accuracy, responsiveness, power efficiency, and adaptability across diverse environments.

II. NEED OF PROJECT

The proportion of individuals with disabilities has been rising in both rural and urban India. Disabilities may be congenital—present from birth—or acquired later in life due to medical conditions, aging, or accidents such as road mishaps or spinal injuries. Regardless of the cause, these impairments can severely affect an individual's ability to perform daily tasks and participate fully in society. A large portion of disabled individuals in India rely on mobility aids, but many conventional solutions like manual wheelchairs demand upper body strength or coordination that not all users possess. This underscores the need for more accessible and adaptive mobility technologies.

Globally, around 1.3 billion people, or one in six individuals, experience significant disabilities. In India, the 2011 census noted that 20.3% of people with disabilities face movement-related challenges. Many disabilities involve movement restrictions.

To address the growing demand for accessible mobility aids, this project introduces an economical yet advanced gesture-based wheelchair system. By leveraging hand gesture recognition, it enhances mobility and independence.

Benefits to people who are:

a. Individuals with paralysis
b. People who crawl
c. Users needing walking aids
d. Those with joint or muscle impairment
e. Individuals with involuntary movements or fragile bones
f. People with coordination disorders
g. Those with lower-body numbness due to paralysis or injuries
h. Individuals with limb deformities or abnormal postures

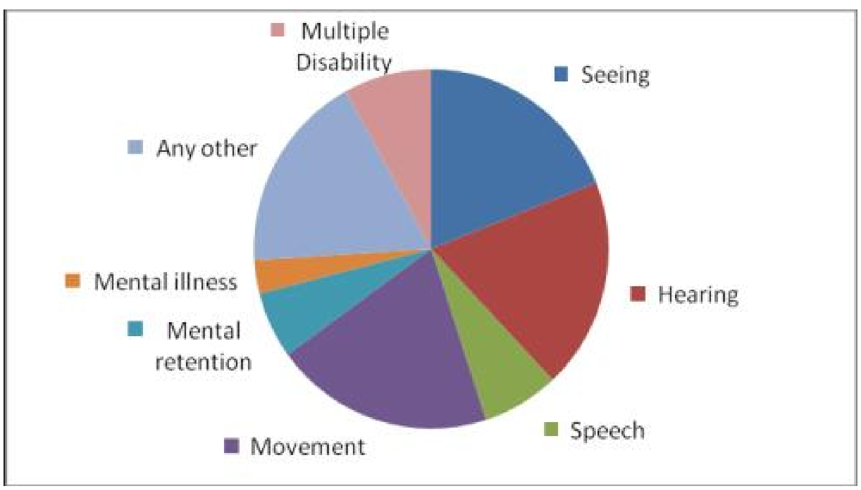


Fig. Percentage of people suffering from different kind of disability

III. LITERATURE REVIEW

Technological progress in assistive mobility has greatly enhanced the quality of life for individuals with physical impairments. Traditional manual and joystick-controlled wheelchairs require physical effort and motor control, which are not feasible for users with severe impairments. Researchers have explored alternative control methods including voice commands, BCIs, and gesture recognition.

Joysticks, while accurate, are only practical for users with sufficient dexterity. For users with neuromuscular issues, manual control becomes problematic. Voice-controlled wheelchairs offer hands-free navigation but are vulnerable to background noise and speech-related limitations. They may not be usable by individuals with speech impairments.

BCI technology enables control through brain signals but requires expensive equipment, complex calibration, and can be unreliable due to signal noise. Thus, BCI systems remain experimental.

Gesture recognition is particularly useful for users with functional upper limbs. MEMS-based sensors can capture hand movements and convert them into directional commands. Combining gyroscopes and accelerometers improves precision and reduces false signals. Yet, challenges like unintended gesture detection, latency, and environmental sensitivity persist.

Comparative studies show trade-offs in each system. Joysticks need fine motor skills. Voice control is environment sensitive. BCI is costly and complex. Gesture control balances usability and cost but needs enhancements in recognition and adaptability.

Persistent issues include low recognition accuracy due to sensor variability and movement inconsistencies. Real-time responsiveness can be hindered by processing delays. Many designs assume standard movement patterns, which may not apply to all users. Environmental conditions like sensor drift and external interference add additional complexity to the situation. Although MEMS sensors are affordable, integrating high-accuracy recognition and communication tools raises costs.

This study aims to develop a refined, real-time gesture-controlled wheelchair that improves recognition accuracy, reduces latency, and adapts to diverse user needs using MEMS sensors, advanced algorithms, and wireless communication.

IV. METHODOLOGY

This project involves the development of a smart wheelchair operated through hand gestures, featuring two main units: a transmitter and a receiver. The accelerometer detects wrist tilts and sends signals wirelessly using RF modules.

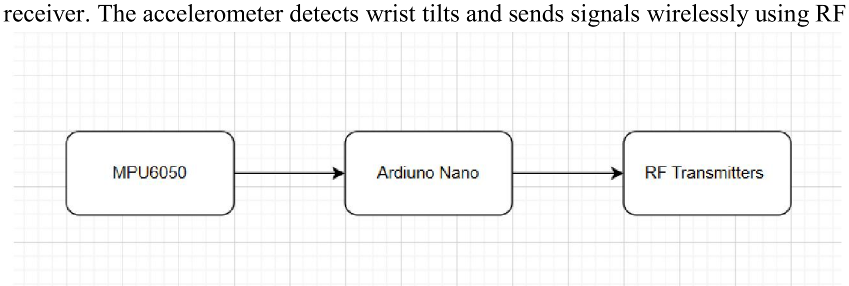


Fig 1. Transmitter Section

Transmitter Section:

Hand movements are detected using the MPU6050 sensor, which combines a 3-axis accelerometer and a 3-axis gyroscope. This sensor communicates with the Arduino Nano through the I2C protocol, delivering motion data that the microcontroller processes and sends wirelessly via an RF transmitter module. On the receiving end, the RF signal is collected and interpreted using an Arduino Uno.

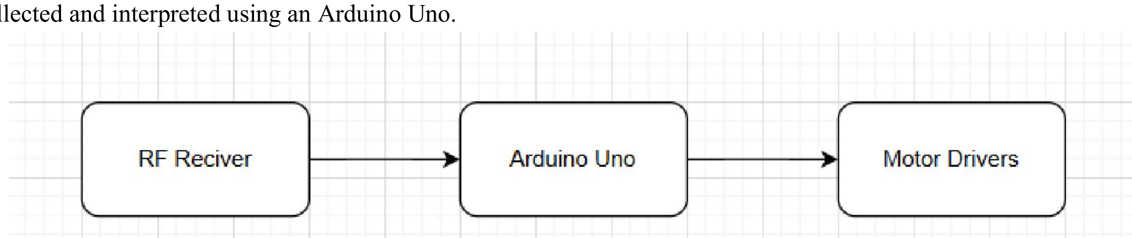


Fig 2. Receiver Section

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, April 2025
Impact Factor: 7.67

Receiver Section:
The receiver unit captures the RF signal and processes it using an Arduino Uno. The processed data is used to control the BTS7960 motor driver, which directs the motors to manoeuvre the wheelchair.

V. COMPONENTS USED

- Wheelchair
- 2 x Brushed DC Motor (24V 250W)
- 2 x Lead Acid Batteries (12V 12Ah)
- 2 xMotor Driver(BTS7960)
- Arduino Uno
- 2 x NRF24L01 (Trans receiver)
- Arduino Nano
- MPU6050 (combines 3-axis Gyroscope, 3-axis Accelerometer)

VI. CIRCUIT DEVELOPMENT

The circuit development represents the proposed wheelchair system. It assembles various circuits together results in schematic representation.

Transmitter Circuit:

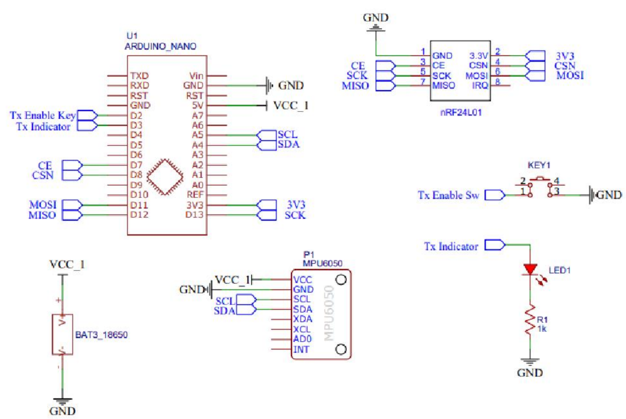


Fig. 3. Circuit Diagram of Transmitter Section

Fig 3. Represents the transmitter circuit for a hand gesture-controlled wheelchair, using an Arduino Nano as the main microcontroller. The transmitter circuit consists of the MPU6050 connected to the Arduino Nano via I2C protocol. Gesture data is processed and sent to the nRF24L01 module, which handles the RF communication. Power is supplied via a compact battery system. Additional components like transmission indicators and activation keys are included.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, April 2025
Impact Factor: 7.67

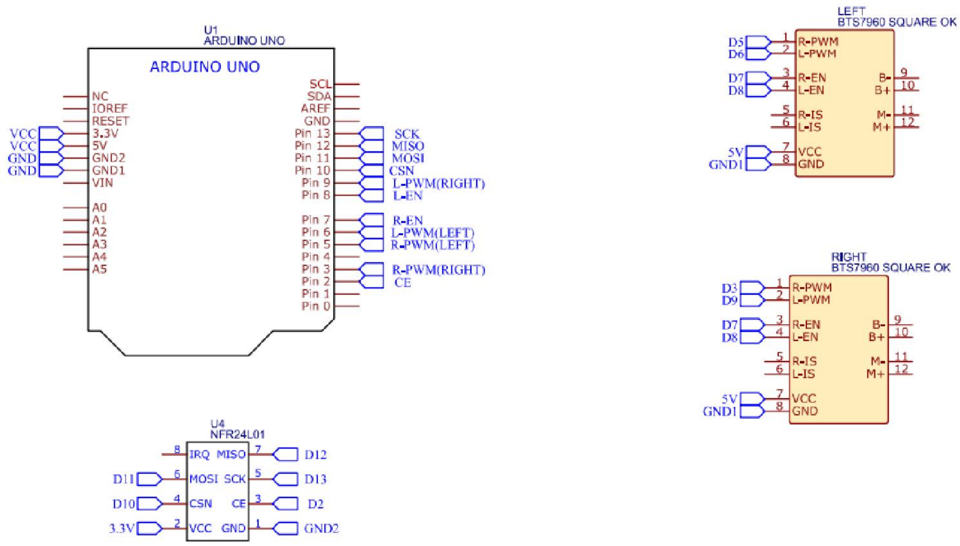


Fig. 4.Circuit Diagram of Receiver Section

The receiver circuit includes the Arduino Uno, which communicates with the nRF24L01 via SPI. Data received from the transmitter is processed to control the BTS7960 motor driver. The motors are powered by a dual battery setup and directed based on gesture inputs, enabling movement in all directions.

VII. WORKING

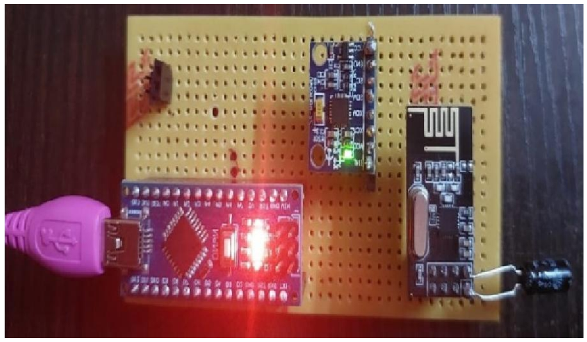
The transmitter section can be placed on the wrist like a wearable device. When a forward tilting is detected from MPU6050 and the values of X and Y axis is transmitted to the micro controller of Arduino in receiver section through RF pair modules, and the motor driver will control the movement of the wheel in forward direction i.e., both the M+ and M- pin of the motor are set as HIGH and rest as LOW. When the value of X and Y (for backward motion) is transmitted over the RF module because of backward tilting of the wrist the motor driver will control the movement in backward direction. Similarly, the right and left tilting will control the movement in right and left direction. Based on the difference in initial value and real-time value read by accelerometer it determines which direction the wrist is moved. Only Acceleration along x and y axis are considered for determining the direction. When the tilt is in forward direction along the x axis the value of x decreases otherwise value increases and when tilting is along the y axis in forward direction the value of y decreases otherwise increases.

Table. Working direction of wheelchair

Hand Direction	Left Motor	Right Motor
Backward	Forward	Forward
Forward	Backward	Backward
Left	Stop	Forward
Right	Forward	Stop

When both the wheels of wheelchair move in forward direction the wheelchair moves forward. When both wheels move backward the wheelchair moves in backward direction. Wheelchair moves in left direction when the left wheel stops and right wheel move forward and to right direction when the right wheel stops and left wheel moves forward.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, April 2025
Impact Factor: 7.67



The above image shows the hardware connection of the transmitter section, consist of Arduino Nano, MPU6050 (combines 3-axis Gyroscope, 3-axis Accelerometer), RF transceiver module, and power supply. This connection will be placed on the wrist like a wearable device. The circuit operate when it gets signal from accelerometer according to the tilt.

The above figure shows hardware connection of receiver section; consist of Arduino UNO, RF transceiver module, BTS7960 motor driver, motors, and power supply. The circuit works when the RF receiver module receives the radio frequency signal from the RF transmitter module.

VIII. SCOPE OF STUDY

The development of a manual gesture-controlled wheelchair holds immense potential in bridging the gap between human cognition and machine interaction. Further advancements in this technology could extend beyond basic hand gesture signals to incorporate speech and brain signal recognition, marking a significant milestone in assisting individuals with complete paralysis.

Enhancing cost-effectiveness while integrating advanced sensing technologies and wireless control mechanisms can make the system more robust and accessible. Features such as head movement detection and eye-tracking using optical sensors can be implemented to improve the wheelchair’s directional control, offering an intuitive and seamless user experience.

Additionally, integrating various safety measures can further enhance user security and independence. Implementing real-time tracking systems would enable continuous monitoring of both the wheelchair and its user, while a GSM-based communication system could facilitate the transmission of critical messages, ensuring immediate assistance when need. These advancements will not only improve mobility solutions but also redefine assistive technologies, making them more intelligent, reliable, and inclusive.

IX. CONCLUSION

This paper presents the fundamental concepts of a hand gesture-controlled wheelchair utilizing an accelerometer as the primary sensor to detect hand movements and govern the wheelchair's direction. The study highlights the significant

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 5, Issue 8, April 2025 Impact Factor: 7.67

challenges faced by individuals with disabilities in carrying out essential daily activities. With the growing prominence of hand gesture recognition systems in human-machine interfaces, they offer an intuitive and efficient means of control. The proposed wheelchair design integrates motion control through embedded hardware-based systems, demonstrating high effectiveness, precision, and competitive performance. The experimental results validate the system's reliability, making it a viable solution for enhanced mobility assistance.

REFERENCES

[1]. Pushpendra Jha and P. Khurana, "Hand Gesture Controlled Wheelchair", *International Journal of Scientific & Technology Research.*, vol. 9, pp. 243-249, 2016.

[2]. R. Anilkumar and A. M. R., "Hand Gesture Controlled Wheelchair," International Journal of Creative Research Thoughts (IJCRT), vol. 11, no. 1, pp. 456-462, Jan. 2023. Available: https://www.ijcrt.org

[3]. Veeraiyan Sridevi, P. Iswarya, Surya Chandra, Podugu and N. Suresh Kumar, "Automated Gesture Based Wireless Wheelchair Control by Means of Accelerometer", *International Journal of Engineering and Advanced Technology.*, vol. 9, pp. 2249-8958, 2019.

[4]. Mufrath Mahmood, MdFahimRizwan, Masuma Sultana, MdHabib and Mohammad Imam, *Design of a low-cost Hand Gesture Controlled Automated Wheelchair*, 2020.

[5]. Swarnika Shruti and SavitaKumariVerma, "Arduino Based Hand Gesture Controlled Robot", *International Research Journal of Engineering and Technology (IRJET)*, 2022.

[6]. Bourhis, G., Moumen, K., Pino, P., Rohmer, S., &Pruski, A. (2002).Assisted navigation for a powered wheelchair. IEEE Xplore. Retrieved November 4, 2022, from https://ieeexplore.ieee.org/document/385072.

[7]. MahipalManda, B Shankar Babu, M Abhishek, & J Srikanth.(2018, September). HAND GESTURES CONTROLLED WHEELCHAIR.https://www.jetir.org/papers/JETIRE006094.pdf.