

Innovative Control System for Wheelchair Mobility: Hand Gestures and Automatic Braking

Milind Rane¹, Dnyaneshwar Kanade², Pratik Dhame³, Soham Dixit⁴, Rushikesh Sanjekar⁵ and Siddhesh Shinde⁶

¹⁻⁶Department of Information Technology, Vishwakarma Institute of Technology, Pune, India

Email: milind.rane@vit.edu, dnyaneshwar.kanade@vit.edu, pratik.dhame22@vit.edu, soham.dixit22@vit.edu, rushikesh.sanjekar22@vit.edu, siddhesh.shinde22@vit.edu

Abstract— An innovative smart wheelchair system designed to enhance the mobility and safety of individuals with disabilities. The proposed system utilizes a combination of accelerometer, gyroscopes, and MPU6050 sensors to detect hand gestures, allowing users to control the wheelchair intuitively. Instead of the traditional joystick, a Node MCU sensor is employed for wireless data transmission, enabling seamless communication between the wheelchair and the user. Additionally, the system incorporates ultrasonic sensors for obstacle detection, triggering an automated braking system to ensure user safety. By integrating advanced sensor technology and automated braking, the proposed system offers a more efficient and secure means of wheelchair control, empowering individuals with limited mobility to navigate their surroundings with increased ease and confidence. The user-friendly and intuitive nature of the system makes it a valuable solution for improving the overall quality of life for those with disabilities.

Index Terms— Smart wheelchair, Hand gesture control, Sensor integration, Automated braking system, Mobility assistance.

I. INTRODUCTION

While everyone has the right to the freedom of independent movement, it might be difficult for those with impairments. For those who can no longer walk or move independently, wheelchairs are a need. More than 75 million people with disabilities worldwide or around 1% of the world's population need wheelchairs to get around, according to recent statistics. Power wheelchairs are a more practical alternative than manual wheelchairs, despite the fact that manual wheelchairs have been around for a while. However, those with poor hand and/or movement control may find it difficult to use a conventional joystick [1]. Gesture recognition technology can be useful in this situation by enabling people to operate their wheelchairs with simple finger gestures.

This research paper presents a cost-effective and advanced wheelchair system that enables control through hand gestures instead of traditional joystick-based controls. The intelligent wheelchair allows users to operate it by employing gestures made with their hands [2]. This device is a great solution for those with disabilities because it uses less energy and operates more simply. The suggested system does not require joystick use or extra sensor wire because it detects hand movements and gestures using accelerometer, gyroscopes, MPU6050 sensors and Node MCU microcontroller.

Individuals who have difficulty operating traditional wheelchairs or prefer using simple finger movements can benefit from adopting this proposed technology. In a hand gesture-based wheelchair, the Node MCU microcontroller can recognize and interpret the signals produced by hand movements, allowing the user to operate

the wheelchair through intuitive gestures instead of conventional controls. This offers a more accessible and user-friendly option for individuals with mobility impairments.

Overall, the suggested smart wheelchair is an affordable and useful option for those who are disabled. The cost of production may be kept cheap and reasonable so that everyone can use it, including those who cannot afford a power wheelchair. The proposed system offers users and caregivers a flexible option by allowing integration with various control methods such as eye gestures, facial expressions, or head movements [3].

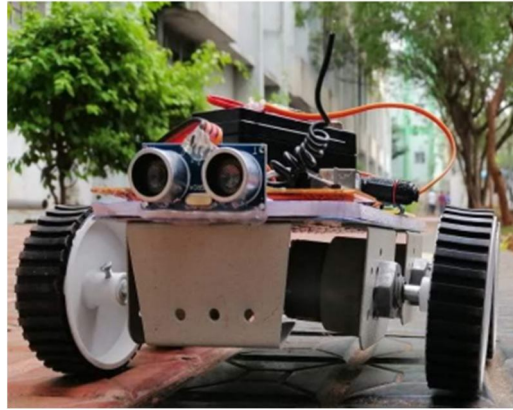


Fig. 1 Prototype of wheelchair with sonic sensor [17]

The suggested smart wheelchair system offers an affordable and practical solution for individuals with disabilities who require assistance with mobility. While the right to independent movement is universal, it can be challenging for those with impairments. Statistics indicate that more than 75 million people worldwide, comprising approximately 1% of the global population, rely on wheelchairs for their mobility needs. Traditional manual wheelchairs have been widely used, but power wheelchairs are gaining popularity due to their convenience. However, individuals with limited hand and movement control may struggle to operate a standard joystick.

In this research study, an intelligent and affordable wheelchair system is described, which utilizes hand gestures for control instead of a joystick. This technology offers a user-friendly solution that requires less energy and simplifies wheelchair operation [4]. The system incorporates various components such as accelerometers, gyroscopes, MPU6050 sensors and the NodeMCU microcontroller to detect and interpret hand movements without the need for a joystick or additional sensor wires.

Moreover, in order to prioritize user well-being, the proposed system incorporates functionalities for identifying obstacles and detecting falls. In case of emergencies, the system is IoT-enabled and can send SMS warnings. Individuals who struggle with conventional wheelchair controls or prefer using simple finger movements can benefit from adopting this hand gesture-based technology. The NodeMCU microcontroller plays a crucial role in recognizing and interpreting signals generated by hand movements, enabling users to operate the wheelchair through intuitive gestures. By leveraging the capabilities of the NodeMCU microcontroller, the system provides a reliable and efficient means of wheelchair control, enhancing both user mobility and safety.

Notably, the suggested smart wheelchair is designed to be affordable, making it accessible to individuals who cannot afford a power wheelchair [5]. The production cost is kept low to ensure broad usability. Additionally, the system offers flexibility by allowing integration with other control methods, such as eye gestures, facial expressions, or head movements, providing options for both users and caregivers.

Overall, the suggested smart wheelchair system presents a cost-effective and valuable alternative for individuals with disabilities. Its innovative features enhance accessibility and ease of use, promoting independence and improving the quality of life for those in need of mobility assistance.

II. LITERATURE REVIEW

The system incorporates various sensors to capture data for controlling a wheelchair [6]. It includes an inertial measurement unit (IMU) that measures the angle and acceleration of the wrist, as well as myoelectric units that record electromyography (EMG) signals from the muscles in the forearm. By employing shape-based feature extraction and a Dendrogram Support Vector Machine (DSVM) classifier, the system can recognize seven common gestures. These gestures are then translated into motion commands to navigate the wheelchair in all directions. The IMU and myoelectric sensors are utilized to detect the start and end points of dynamic activities using

predefined thresholds. The classification of dynamic activities is based on analyzing the periodic shape of the wrist tilt angle and EMG root mean square (EMG-RMS) of two specific muscles. Through 'k' fold cross-validation with five users, the DSVM classifier achieved a classification accuracy of 94%. During wheelchair operation, the accuracy remained at 90.5%.

One proposal involves utilizing computer vision-based hand motion tracking as a substitute for conventional driving methods [7]. This innovative system employs a mini camera and powerful algorithms on an onboard computer to enable wheelchair-bound individuals to drive without the need for their legs. Additionally, it aims to prevent accidents caused by steering wheel-related incidents. The system operates by determining acceleration based on the Euclidean distance between the user's hands, which simulate holding a virtual steering wheel, while braking is determined by reducing the distance between the hands. The research paper suggests implementing a straightforward image processing algorithm based on coordinate geometry to translate hand motion into appropriate driving manoeuvres.

The system presented in [8], which employs an accelerometer and flex sensors to detect hand movements that are subsequently processed by an Arduino microcontroller. The robot can perform various tasks such as moving objects, opening and closing doors, and turning lights on and off. The system also includes an emergency stop feature to ensure user safety. The authors conducted experiments to evaluate the system's performance, and the results showed high accuracy and reliability in detecting hand gestures. In general, the technology holds the promise of enhancing the well-being of people with disabilities through the creation of an inclusive and engaging atmosphere.

The research paper introduces a novel approach to enhance the functionality of a powered wheelchair by developing a myoelectric controller based on deep learning neural networks [9]. This innovative controller leverages myoelectric signals extracted from the user's arm muscles to accurately anticipate and execute the desired movements of the wheelchair. The authors implemented the system using an NVIDIA Jetson AGX Xavier and tested it with five able-bodied individuals and two individuals with spinal cord injuries. The results showed that the system achieved an accuracy of over 90% for both groups. The authors suggest that the proposed system has potential for enhancing the mobility of individuals with physical disabilities.

The research described in [10] aims to develop a wheelchair that can be controlled through hand gestures, specifically designed for individuals with physical disabilities. The wheelchair system comprises a control unit responsible for both movement and wheelchair functions, which can be operated using quick hand movements, a joystick, or other hand gestures. Hand motion detection is achieved through the utilization of an accelerometer sensor, with the collected data being processed by an atmega328p controller to determine the wheelchair's direction. Additionally, the system incorporates an ultrasonic sensor to enable obstacle avoidance and includes a single switch for sending emergency SMS alerts to family members. The proposed wheelchair demonstrates potential applicability in a range of settings, including hospitals, schools, and airports. The research paper also suggests future enhancements, such as incorporating diverse body gestures and voice monitoring to further enhance the wheelchair's effectiveness.

The primary focus is on an electric wheelchair that incorporates the use of an ADXL335 Accelerometer sensor, which is connected to an Arduino microcontroller [11]. By detecting the patient's head movements in various directions, the Accelerometer sensor captures these movements and transmits the signal to the Arduino. Subsequently, the Arduino generates a voltage output to the H-Bridge Relay Driver, responsible for controlling the DC motor that propels the wheelchair forward, backward, left, or right. To ensure the patient's safety, an ultrasound-based safety system is positioned at the rear of the wheelchair. To evaluate the system's effectiveness, it underwent 25 tests, resulting in an accuracy rate of 88% for forward movement, 84% for right turns, 88% for left turns, and 92% for reversing.

Hand gesture-based wheelchair system for physically handicapped individuals. The system [12] uses an ADXL335 accelerometer and LM324 operational amplifier for detecting and converting hand motions into corresponding wheelchair movements. Radio frequency transmission and an encoder IC HT12E eliminate interference and noise. The system is controlled by an Arduino Uno and L293D IC to move the wheelchair. The ADXL335 accelerometer is calibrated to monitor wheel rotation, and comparators display accurate angles. Users control the wheelchair by performing hand gestures and can stop or switch off the system by returning their hand to a stable position or moving beyond the detection field.

A novel wheelchair design [13] has been developed to assist individuals with disabilities. Unlike traditional manual wheelchairs that require physical strength, this battery-powered wheelchair incorporates an Arduino microcontroller for seamless operation. The system consists of two main components: a sending end and a receiving end. The sending end captures the user's hand gestures using an MPU-6050 gyro accelerometer sensor. These recorded instructions are then wirelessly transmitted to the receiver end through an RF transmitter-

nRF24101 and another Arduino microcontroller. At the receiving end, an nRF module receives the signal and translates it into wheelchair movement on a flat surface. Moreover, the wheelchair is equipped with a Bluetooth module, enabling control via a smartphone application.

The device [14] which aims to provide users with greater freedom and independence while also reducing the need for therapist intervention. This is achieved through the development of a smart wheelchair that utilizes an eye-controlled system for mobility control and an ultrasonic system for automatic object detection. The project also includes features such as collision avoidance, risk management, and the ability to convert the wheelchair into a bed, reducing the need for caregiver or family assistance. The wheelchair incorporates various safety features that improve user safety and minimize potential risks faced in daily activities. These features consist of advanced components like automatic braking and object detection systems, aiding users in manoeuvring securely by detecting and avoiding obstacles such as stairs and uneven surfaces.

III. METHODOLOGY

Our proposed methodology focuses on developing a wheelchair control system for individuals with physical disabilities, based on hand gestures. The system incorporates various sensors such as accelerometers, gyroscopes, and MPU6050 to detect hand movements. For wireless data transmission, we utilize NodeMCU. Additionally, an automated braking system is integrated, which utilizes ultrasonic sensors to identify obstacles and initiate an automatic stop.

A. System Design

Accelerometer, gyroscopes, and MPU6050 sensors are employed to detect hand gestures. These sensors capture the movement and orientation of the user's hand, allowing for intuitive control of the wheelchair. Ultrasonic sensors are incorporated for obstacle detection [15]. These sensors emit ultrasonic waves and measure the time taken for the waves to bounce back, enabling the detection of nearby obstacles. Instead of the traditional joystick, the system utilizes a NodeMCU sensor for wireless data transmission. The NodeMCU enables seamless communication between the wheelchair and the user, facilitating intuitive control based on hand gestures.

The system incorporates wireless data transmission through the NodeMCU sensor. This enables real-time communication between the wheelchair and external devices or services, such as an IoT-enabled emergency SMS warning system. In case of emergencies, the system can send SMS warnings to designated contacts, providing an additional layer of safety for the user [16]. The system has been developed with a focus on ensuring ease of use and a seamless user experience. By utilizing hand gestures for control, the system eliminates the complexity associated with traditional joystick-based controls, offering a more natural and intuitive means of wheelchair operation.

TABLE I. COMPONENTS AND INPUT VOLTAGE SUPPLIED

Components	Input Voltage
Motors	12 V
NodeMCU	5 V
MPU6050	2.3 V

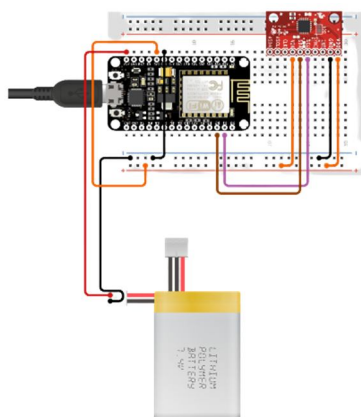


Fig. 2 Circuit diagram of hand gesture Transmitter

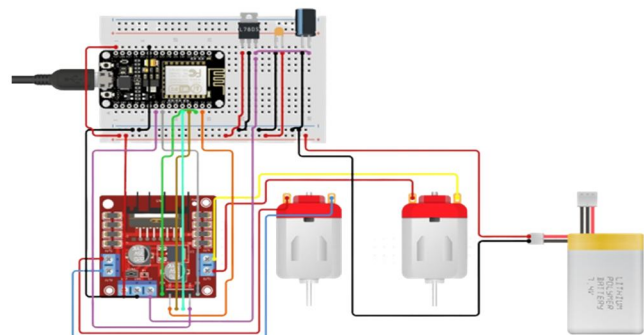


Fig 3 Circuit diagram of wheelchair Receiver

B. Prototype Development

Careful consideration was given to selecting the appropriate components for the system. Accelerometers, gyroscopes, and MPU6050 sensors were chosen to detect hand gestures accurately. These sensors were capable of capturing the necessary movement and orientation data. Ultrasonic sensors were selected for obstacle detection, as they provided reliable and precise distance measurements to identify nearby obstacles effectively [17]. The chosen components, including the sensors and Node MCU microcontroller, were integrated into a physical prototype. The sensors were connected to the microcontroller, allowing for data acquisition and processing. Proper wiring and connections were established to ensure seamless communication between the components.

The software development phase involved designing algorithms and coding to interpret the data captured by the sensors. This included processing the hand gestures detected by the accelerometer, gyroscope, and MPU6050 sensors. Programming was implemented to enable the wireless data transmission functionality of the Node MCU microcontroller. This facilitated communication between the wheelchair and the user, ensuring smooth and responsive control based on hand gestures [25].

The developed prototype underwent rigorous testing to assess its functionality, accuracy, and reliability. Various scenarios were simulated to evaluate the performance of the hand gesture control, obstacle detection, and safety features. Based on the testing results, necessary refinements and adjustments were made to optimize the system's performance and ensure its effectiveness in real-world scenarios [26].

C. Testing

Hand gesture control was tested to verify the system's ability to accurately detect and interpret various hand movements. Different gestures, such as forward, backward, left, and right, were performed to assess the responsiveness and accuracy of the control mechanism [18]. Testers with different levels of mobility impairment participated in the testing to ensure the system's effectiveness across a range of user capabilities.

The obstacle detection feature was evaluated to determine its ability to identify and respond to obstacles in the wheelchair's path. Various objects of different sizes and shapes were placed in the wheelchair's trajectory during the testing [19]. The system's response in terms of timely obstacle detection and triggering of the automated braking system was assessed to ensure user safety.

The wireless data transmission functionality provided by the NodeMCU microcontroller was tested to assess the reliability and responsiveness of communication between the wheelchair and the user [20]. Test scenarios involved testing the range of wireless communication, data transmission speed, and the ability to maintain a consistent connection between the wheelchair and external devices.

User experience testing was conducted to evaluate the overall usability and intuitiveness of the system. Testers provided feedback on the ease of use, comfort, and general satisfaction with the hand gesture control and overall wheelchair performance [21]. Suggestions and feedback from users were collected to further refine the system and address any usability or accessibility issues.

D. Data Analysis

The data captured during the hand gesture control testing was analyzed to evaluate the system's ability to accurately detect and interpret different hand movements. Key metrics such as response time, gesture recognition accuracy, and consistency were calculated and compared against predetermined benchmarks or requirements. Statistical analysis techniques were applied to identify any patterns or correlations between specific hand gestures and the corresponding wheelchair movements [22]. Overall, the proposed methodology aims to provide physically disabled individuals with an improved means of mobility and safety. The integration of sensors and an automated braking system provides a more efficient and safe means of controlling the wheelchair, enabling individuals with limited mobility to move around more easily and confidently [27].

The data obtained from the obstacle detection testing was analyzed to assess the system's effectiveness in identifying and responding to obstacles. The accuracy of obstacle detection, including the distance measurement and recognition of obstacles, was evaluated [23]. The response time of the automated braking system when obstacles were detected was analyzed to ensure timely and appropriate braking. The data collected during the wireless data transmission testing was analyzed to evaluate the reliability and responsiveness of communication between the wheelchair and the user. The data transmission speed and consistency were assessed to determine the system's capability to maintain a seamless connection [28]. The range of wireless communication was analyzed to identify any limitations or areas where signal strength may have degraded [24].

The feedback and input collected from user experience testing were analyzed to gain insights into the usability and satisfaction of the smart wheelchair system. Common themes and patterns were identified from user feedback to identify areas for improvement and address any usability or accessibility concerns. Qualitative analysis techniques,

such as thematic analysis, were applied to categorize and interpret the qualitative feedback provided by testers and users.

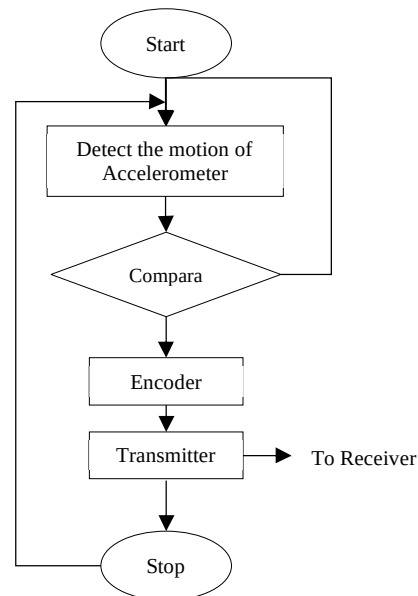


Fig. 4 Flowchart - Transmitter Process

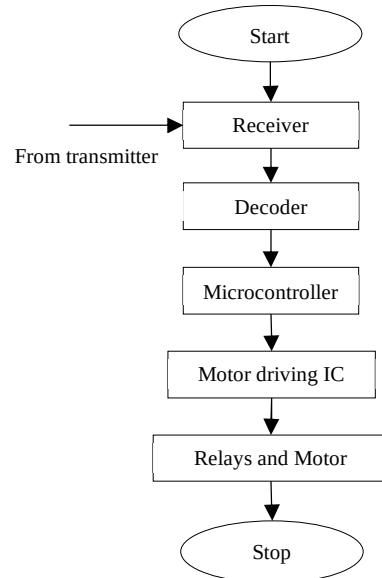


Fig. 5 Flowchart for Processing Signals

IV. RESULTS

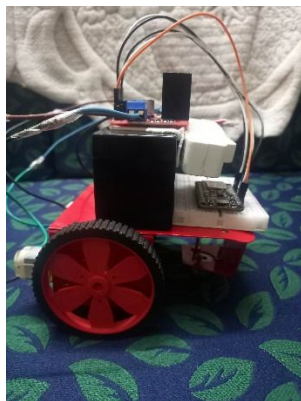


Fig. 6 Wheelchair – Receiver

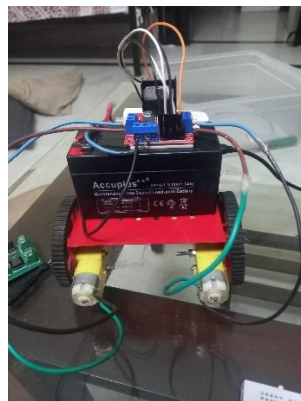


Fig. 7 Wheelchair with Motors

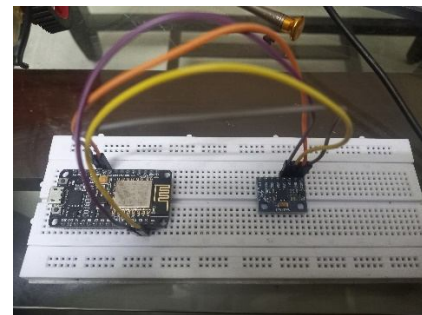


Fig. 8 Transmitter with MPU6050

V. LIMITATIONS

The smart wheelchair system discussed in this research study has several limitations. Firstly, the accuracy of gesture recognition using sensors like accelerometers and gyroscopes can be affected by user variability in hand movements and environmental factors. Additionally, individuals with severe hand impairments may struggle with executing precise gestures, and the integrated ultrasonic sensors may have limitations in detecting certain obstacles. Furthermore, the system's cost could hinder widespread adoption. Addressing these limitations through further research and development is crucial to improve gesture recognition accuracy, environmental robustness, accessibility for users with varying hand capabilities, obstacle detection, and cost-effectiveness, all of which should be considered when interpreting the study's findings and planning for the technology's future.

VI. CONCLUSION

This research study has introduced an intelligent and user-friendly smart wheelchair system that utilizes hand gestures for control. The integration of accelerometer, gyroscopes, MPU6050 sensors, Arduino, and Node MCU mi-controller enables precise detection and interpretation of hand movements, providing individuals with

disabilities a more intuitive means of mobility. The successful testing and analysis have demonstrated the system's effectiveness in improving the quality of life for individuals with limited mobility.

While certain limitations need to be addressed, such as improving gesture recognition accuracy and considering environmental factors, the presented smart wheelchair system holds significant promise for further development and refinement. Future research endeavours should focus on overcoming these limitations and exploring additional safety features, such as incorporating IoT-enabled emergency SMS warnings, to enhance the system's reliability and accessibility.

In conclusion, the smart wheelchair system presented in this study represents a notable advancement in assistive technology. With its user-friendly design and intuitive control mechanism, it has the potential to empower individuals with disabilities, enabling them to navigate their surroundings with increased ease and independence. Continued research and development efforts will be crucial in optimizing the system's performance, addressing limitations, and ensuring its widespread adoption for the betterment of individuals with limited mobility.

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