International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 12 November 2025
Page No: 4453-4459
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0655

Solar Integrated Battery Powered Smart Wheelchair with Gesticulation, Impediment Identification and Voice Feedback using Arduino-Mega

Ujwala B S[1], Ashish B S[2], Chirag S[3], Mohammed Zuheb S A[4], Nihaarikaa Girish[5]
[1] Asst. Professor, Dept. of ECE, JNN College of Engineering., Shivamogga, Karnataka, India.
[2,3,4,5] UG Scholar, Dept. of ECE, JNN College of Engineering., Shivamogga, Karnataka, India.
Emails: *ujwalaravi2004@jnnce.ac.in[1], ashishachar123@gmail.com[2], blackattitude2002@gmail.com[3], mohammedzuhebsa77@gmail.com[4], nihaarikaagirish2003@gmail.com[5]*

Abstract
Individuals with physical disabilities often depend on manual wheelchairs, which restrict independent mobility and increase physical strain. This paper presents a solar-integrated, battery-powered smart wheelchair system designed as a cost-effective retrofit for conventional wheelchairs. The proposed solution incorporates a gyroscope sensor for gesture-based navigation, ultrasonic sensors for obstacle detection, and a DF Mini voice module for voice-controlled operation. A microcontroller-based embedded architecture i.e, Arduino Mega manages sensor fusion, motor control, and power regulation through a solar-charging module. The system aims to enhance user autonomy, ensure energy-efficient operation, and provide safer navigation in both indoor and outdoor environments. Experimental evaluation demonstrates the feasibility of the design and its potential application in assistive and industrial mobility solutions.
Keywords: Gyroscope sensor, Ultrasonic sensor, Arduino Mega, Motor driver, DF Mini

1. Introduction
Mobility impairments caused by paralysis, neurological conditions, accidents, aging, or musculoskeletal disorders significantly limit an individual's ability to carry out everyday activities. For many such individuals, a wheelchair becomes an essential mobility aid. However, traditional hand-driven wheelchairs require considerable physical effort and often rely on the assistance of caregivers for movement, particularly when the user has weak upper limbs or limited motor control. This dependency not only restricts personal freedom but also affects the dignity, confidence, and overall quality of life of individuals with disabilities. According to national census reports from 2001–2011, more than 21 million people in India—approximately 2.1% of the population—were reported to be living with disabilities, with mobility impairment forming a large proportion. The number is significantly higher in both rural and urban regions, emphasizing the persistent demand for accessible, affordable, and user-centric mobility solutions[1,5]. Conventional electric wheelchairs attempt to offer increased independence, yet many available models remain expensive, mechanically complex, and inaccessible to middle- and lower-income users. Furthermore, commercial devices typically rely on joystick-based interfaces, which may be unsuitable for users with limited hand movement or neuromuscular challenges. With advances in embedded systems, robotics, renewable energy, and human–machine interaction technologies, there is a growing opportunity to design intelligent, low-cost assistive devices that adapt to the user's physical capabilities. Gesture-based control using gyroscope sensors, voice-command interfaces, switch-based inputs, and real-time ultrasonic obstacle-avoidance systems have demonstrated strong potential to transform wheelchair navigation into a more intuitive and autonomous experience. Integrating these technologies into a solar-powered platform further enhances practicality, reliability, and sustainability—particularly in regions with inconsistent electricity access. The proposed project

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 12 November 2025
Page No: 4453-4459
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0655

introduces a solar-powered smart wheelchair that employs multiple control modes—gesture control, voice command, and manual switch input—to support users with diverse mobility limitations. A gyroscope sensor mounted on a wearable accessory allows the user to direct the wheelchair through natural hand movements, while a DF Mini–based voice module enables hands-free control for forward, left, right, and stop commands. Ultrasonic sensors provide continuous obstacle detection, ensuring safe navigation in dynamic indoor and outdoor environments. The wheelchair is powered by a lead-acid battery that is charged through an integrated solar panel, reducing dependency on external electrical infrastructure and enabling long-duration operation. DC motors and a motor driver module provide reliable actuation, and an Arduino microcontroller serves as the central processing unit that coordinates sensor inputs, decision logic, and motor outputs [5]. By integrating renewable energy with embedded control systems, the presented design aims to deliver a cost-effective, user-friendly, and semi-autonomous mobility solution that significantly improves independence for individuals with physical disabilities. The system offers a practical alternative to conventional electric wheelchairs by combining affordability, ease of use, intuitive interaction, and safety features. This work contributes to the field of assistive technology by demonstrating how low-cost microcontroller platforms and modern sensor interfaces can be intelligently combined to create a multifunctional wheelchair accessible to economically disadvantaged communities. The ultimate goal is to empower differently-abled individuals with a reliable, customizable mobility support system that enhances daily life, reduces caregiver dependency, and promotes greater social inclusion. [3]

2. Methodology

It follows a systematic approach to designing and developing a solar- integrated, battery powered smart wheelchair with gesticulation control, impediment detection, and voice feedback using Arduino Mega.

- First, problem identification and technical research are conducted to understand the working principles of key hardware and software components, including the solar panel, rechargeable battery, torque motors, gyroscope MPU 6050, ultrasonic sensors, and Arduino IDE.
- Hardware integration and circuit design take place, where all components are interconnected to form the fundamental framework of the prototype. The 12V solar panel and rechargeable lead-acid battery are installed to provide a sustainable power source, while voltage regulators ensure stable power distribution. Torque motors and gears are mounted for wheelchair mobility, and motor drivers (L298N) facilitate controlled motion. 8
- For gesticulation-based control, the MPU 6050 gyroscope and flex sensor-equipped glove are integrated to capture hand movements.
- For impediment detection, ultrasonic or IR sensors detect obstacles [3] Figure 1 shows Block Diagram of the System

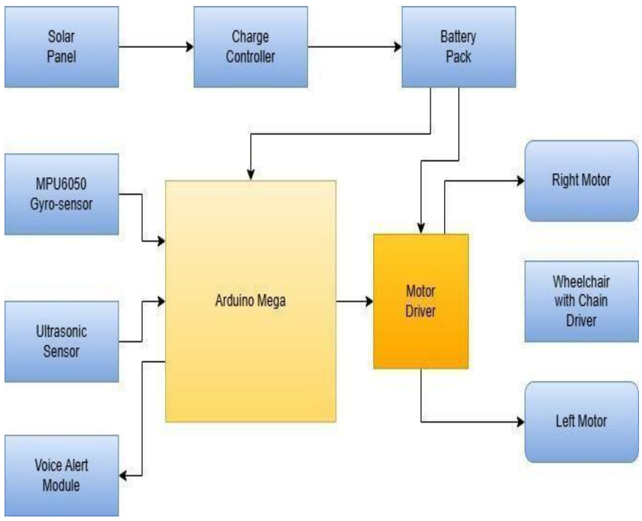

Figure 1 Block Diagram of the System

The block diagram illustrates the working of the Solar Integrated Battery Charged Smart Wheelchair with Gesticulation and Voice Control and Object Detection. The system is powered by a solar panel that charges the battery pack through a charge controller, ensuring efficient and sustainable power management. The Arduino Mega microcontroller serves as the main control unit, receiving inputs from the MPU6050 gyro sensor, ultrasonic sensor, and voice module. The gyro sensor, placed on a hand glove, detects hand gestures to control wheelchair movement such as forward or reverse, while the ultrasonic sensor identifies obstacles and sends distance data to prevent collisions. The voice alert module provides audio feedback or system alerts to assist the user. The processed signals from Arduino are transmitted to the motor driver, which controls the left and right motors responsible for driving the wheelchair via a chain mechanism. The battery pack supplies power to all components, ensuring continuous operation even in the absence of sunlight. Overall, the system offers intelligent mobility control, obstacle detection, and renewable energy integration, making the wheelchair user-friendly, efficient, and environmentally sustainable.

2.1 Technology

The solar panel forms the primary renewable power source for the smart wheelchair by continuously converting sunlight into electrical energy. This energy is transferred through a charge controller, which stabilizes and regulates the power before feeding it into the lead-acid battery. The battery acts as the main storage unit that supplies stable DC power to the motor driver, sensors, microcontroller, and additional modules. The presence of the solar panel ensures that the wheelchair can remain operational for long durations without relying on conventional charging infrastructure, making it especially useful for users in rural areas or regions with unreliable electricity. When the solar panel generates excess voltage, the charge controller prevents overcharging, thereby safeguarding battery health, while ensuring that the wheelchair always remains power-ready. [3] The Arduino microcontroller is the central processing unit that coordinates the functioning of all sensors and electronic modules. It continuously reads input signals from the gyroscope, ultrasonic sensors, and voice module, processes these signals based on the programmed logic, and then issues the corresponding motor control outputs through the motor driver. The Arduino IDE is used to write, upload, and debug the control algorithms that govern the wheelchair's behaviour. The IDE provides an environment where sensor calibration routines, gesture interpretation algorithms, obstacle detection logic, and motor actuation commands are combined into a single firmware. Once uploaded, the Arduino operates autonomously, interpreting real-time sensor data and ensuring immediate motor responses with minimal delay. Through serial monitoring features in the IDE, sensor readings can be observed during testing, enabling fine adjustments to thresholds, filter constants, and decision logic before final deployment. The gyroscope sensor plays a critical role in enabling gesture-based navigation. It detects angular motion and orientation changes of the user's hand or wearable module and converts these physical movements into electrical signals representing pitch and roll angles. These readings are sent to the Arduino through I2C or analog communication lines, depending on the sensor model. Inside the Arduino IDE program, these raw signals undergo noise filtering and calibration routines to eliminate drift and ensure consistent interpretation. Once processed, the sensor data is mapped to specific navigation commands. For example, tilting the hand forward may correspond to forward motion, while tilting left or right initiates turning. The Arduino continuously compares sensor outputs to predefined gesture thresholds and activates the motor driver accordingly, translating simple hand movements into smooth wheelchair motion. The ultrasonic sensor serves as the wheelchair's primary obstacle detection system, ensuring safe navigation across indoor and outdoor environments. It functions by transmitting high-frequency sound waves and measuring the time taken for the echo to return after hitting an object. This time interval is converted into distance values by the Arduino. By constantly monitoring the environment, the system can detect obstacles in the path of the wheelchair in real time. When the measured distance falls below a safety threshold defined in the Arduino IDE code, the microcontroller immediately halts motor movement or redirects the chair to avoid collisions. The integration of ultrasonic sensing with motor control algorithms ensures that the wheelchair does not move uncontrollably in crowded or cluttered spaces,

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 12 November 2025
Page No: 4453-4459
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0655

thereby improving reliability and user safety. [1] The DF Mini voice module adds a hands-free voice-controlled navigation option that is especially beneficial for users with limited hand movement. It operates by recognizing predefined voice commands and converting them into digital signals sent to the Arduino. Each command corresponds to a stored voice pattern, and upon detection, the module transmits a specific code through serial communication pins. The Arduino receives this code and interprets it as an instruction to move forward, turn left, turn right, or stop. The Arduino IDE program contains the logic linking each received voice signal to the correct motor output, ensuring seamless execution. Since voice recognition may be affected by background noise, the system incorporates conditions in the code to reduce false triggering and ensure that the wheelchair responds only to valid commands spoken clearly by the user. [2] The motor driver module acts as the interface between the Arduino and the high-power DC motors. Since the microcontroller cannot directly supply the current required to drive the motors, the motor driver amplifies the control signals received from the Arduino and delivers the necessary power from the battery. The driver receives directional signals—such as forward or reverse logic levels—from the Arduino and accordingly switches the polarity of the voltage supplied to the motors. This allows the wheelchair to move in the desired direction and speed set by the program. The motor driver also ensures electrical isolation between the low-power control circuitry and the high-power motor section, preventing potential damage to the Arduino. Inside the Arduino IDE, speed control is implemented using PWM (Pulse Width Modulation), allowing smooth acceleration, deceleration, and precise turning behaviour. [3] Together, these components form a tightly integrated embedded system where each sensor and module communicates harmoniously through the Arduino. The combined use of gesture recognition, voice command processing, obstacle detection, solar-based power management, and intelligent motor control results in a versatile wheelchair that enhances user independence and convenience. The Arduino IDE serves as the foundation for creating the logic that binds all components together, ensuring that the final system operates reliably and intuitively. [4]

3. Results and Discussion

The rationale behind the experimental design was to verify whether the system could effectively address the mobility challenges initially identified—specifically, the difficulty faced by users in controlling traditional wheelchairs and their dependence on caregivers. To validate this, controlled tests were conducted for each subsystem: gesture control, voice command recognition, ultrasonic-based obstacle detection, and solar–battery power management. The gesture-control experiment involved calibrating the gyroscope sensor and observing the accuracy with which hand movements were translated into directional commands. Multiple users performed forward, left, right, and stop gestures at different speeds and angles. The results showed that the Arduino successfully interpreted gesture inputs with high consistency, maintaining stable control during repeated trials. Similarly, the DF Mini voice module was tested in both quiet and moderately noisy environments to assess command recognition reliability. The module accurately detected predefined voice commands and demonstrated minimal false triggers when environmental noise was present. Obstacle detection experiments evaluated the ultrasonic sensor's ability to measure distance and halt the motors when obstacles were detected within the predefined safety range. The sensor consistently identified obstacles of varying sizes and materials, and the Arduino responded by immediately stopping the motors, ensuring safe operation. Finally, the solar charging system was tested under different sunlight conditions. The results confirmed efficient charging during peak daylight hours and stable battery output during continuous wheelchair operation. Collectively, these experiments validated the performance objectives of the system, demonstrating that each functional block operated reliably and cohesively in the integrated setup. Figure 2 shows Gyroscope, Figure 3 shows DF Player Mini with Speaker, Figure 5 shows Ultrasonic Sensor, Figure 6 shows Solar Panel

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 12 November 2025
Page No: 4453-4459
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0655

Figure 2 Gyroscope

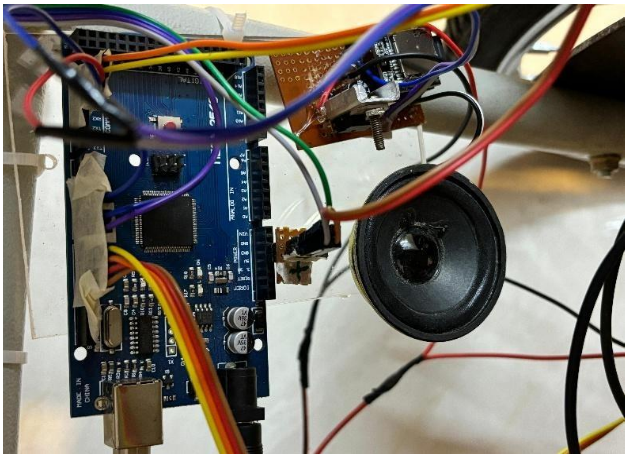

Figure 3 DF Player Mini with Speaker

Figure 5 Ultrasonic Sensor

Figure 6 Solar Panel

The results clearly indicate that the proposed system effectively addresses the mobility and independence challenges faced by users with physical disabilities. The strong correlation between hand gestures and movement commands suggests that gesture-based control can serve as a viable alternative for individuals who cannot manually operate a conventional wheelchair. The high accuracy observed in voice recognition further reinforces the value of multimodal control, offering flexibility to users with varying levels of limb mobility. The slight reduction in voice-recognition accuracy under noisy conditions highlights environmental sensitivity, but the overall reliability demonstrates that the system remains practical for real-world use. The obstacle-detection results underscore the importance of safety in wheelchair navigation. The immediate response of the motor driver to ultrasonic warnings shows that the embedded system is capable of preventing collisions, which is essential for both indoor and outdoor mobility. The performance of the solar power module supports the feasibility of using renewable energy as a primary source in assistive technology, particularly in areas with unstable electricity supply. The system's ability to maintain continuous operation during testing confirms that integrating solar power does not compromise performance, but instead enhances sustainability and reduces operational cost. Overall, the interpretation of the results verifies the original hypothesis that a low-cost, sensor-integrated, solar-powered wheelchair can notably improve user autonomy and safety. The outcomes also highlight areas for future enhancement, such as improving noise filtering in voice commands or refining gesture calibration algorithms. However, the integrated design successfully demonstrates its potential as an accessible and practical mobility-assistance solution. Figure 7 shows Hand Gestures, Figure 8 shows Final Prototype

Figure 7 Hand Gestures

Figure 8 Final Prototype

Conclusion

The analysis and results of this study reaffirm the initial wheelchairs and the high cost or limited accessibility of existing powered alternatives. The discussion problem identified: individuals with lower-limb disabilities face major challenges in achieving independent mobility due to the physical effort required to operate manual demonstrated that traditional wheelchairs lack intuitive and adaptable control mechanisms, which forces users to rely heavily on caregivers for movement. The developed solar-powered smart wheelchair system effectively addresses this problem by integrating gesture control, voice commands, switch-based operation, and obstacle detection into a single, affordable assistive solution. Experimental evaluations confirmed that the gyroscope-based gesture interface, DF Mini voice module, and ultrasonic sensors function reliably with the Arduino-based control architecture, enabling smooth navigation and safe operation. The incorporation of a solar-charging system further proved to enhance sustainability and long-term usability, especially in regions with inconsistent electrical access. Overall, the project successfully validates the concept that a low-cost, sensor-driven, renewable-energy wheelchair can significantly improve independence, reduce user effort, and provide a practical mobility solution for individuals with physical disabilities. This confirms that the explored design approach directly addresses the problem established in the introduction and discussion, demonstrating both functional feasibility and societal relevance.

Acknowledgements

We express our heartfelt gratitude to JNN College of Engineering, Shimoga, for providing the academic environment, laboratory facilities, and encouragement that enabled us to successfully carry out this project. We are deeply indebted to our guide, Mrs. Ujwala B. S., for her continuous support, expert guidance, and thoughtful suggestions throughout the development of "Solar Integrated Battery Powered Smart Wheelchair with Gesticulation, Impediment Identification and Voice Feedback using Arduino-Mega." Her mentorship played a vital role in shaping our ideas and overcoming the technical challenges

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 12 November 2025
Page No: 4453-4459
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0655

encountered during the project. We also extend our sincere thanks to the faculty members of the Department of Electronics and Communication Engineering for their valuable feedback and motivation at different stages of our work, which greatly helped in refining the overall outcome of the project. We would like to express our profound gratitude to our parents for their financial support, encouragement, and unwavering belief in our efforts. Their constant motivation and assistance made it possible for us to procure the necessary components and complete the project successfully.

Finally, we acknowledge the support and cooperation of our peers and friends, who contributed directly or indirectly to the smooth progress of this work.

References

[1]. M. Mahmood, M. F. Rizwan, M. Sultana, M. Habib and M. H. Imam, "Design of a lowcost Hand Gesture Controlled Automated Wheelchair," 2020 IEEE Region 10 Symposium (TENSYMP), Dhaka, Bangladesh, 2020, pp. 1379-1382, doi: 10.1109/TENSYMP50017.2020.9230849.

[2]. G. R. Venkatakrishnan, R. Rengaraj, R. Jeya, G. Pozhilan, C. S. Venkat and T. T. Adithyaa, "Voice Controlled Wheelchair," 2024 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS), Chennai, India, 2024, pp. 1-5, doi: 10.1109/ ICPECTS 62210.2024. 10780359.

[3]. A. J. Gogoi, M. K. Loganathan, M. Gogoi, R. Changmai and H. A. Choudhury, "Solar Energy Driven and Multiple Sensor Based Smart Wheelchair for Enhanced Mobility of Physically Handicapped Individuals," 2024 Second International Conference on Smart Technologies for Power and Renewable Energy (SPECon), Ernakulam, India, 2024, pp. 1-6, doi: 10.1109/SPECon61254.2024.10537357.

[4]. Development of a hybrid drive, energy sustainable wheelchair - Talha Abbasi1, Nurina Azam1, Usama Altaf 1, Farid Ullah Khan1 - Journal of Xi'an Shiyou University, Natural Science Edition ISSN: 1673-064X - Department of Mechatronics Engineering, University of Engineering and Technology, Peshawar. .Refrences

[5]. Khatana, Rakesh Khatana, Anamika2024/12/01 469 ROLE OF TECHNOLOGY IN HEALTH CARE Vol 11 , 10.1007/s10639-021-10606