International Transactions on Electrical Engineering and Computer Science
K. Neelima et.al., Vol: 5, No: 1, pp: 35-43, March 2026

Design and Development of a Prototype Smart Wheelchair Control System for Enhanced Accessibility and Safety

K. Neelima[1], Sura Haricharan[1], Bhukya Vamsi[1], Verpula Pranav[1], Chettipelly Abhinay[1]

Abstract: The paper will explain how the smart wheelchair control system was constructed. The wheelchair control system addresses the limitations of existing systems and makes traveling easier and safer. The smart wheelchair control system allows an individual to operate the wheelchair via smartphone Bluetooth application. The smart wheelchair control system also employs sensor to detect obstacles in order to detect objects and avoid collision. The smart wheelchair control was constructed using an Arduino Uno, HC-05 Bluetooth component, L298N motor controller and ultrasonic sensor HC SR04. The obstacle detecting was 90% correct as revealed through the tests. The power consumption was 25watts and the system will provide 28 minutes of operation on a 12 V, 1 Ah battery. The system will allow the future advancement features of the system including IoT and AI which will be supported by the system, compares to the existing systems including the voice and EMG systems which are currently being used in other systems and keeps the other systems down by 25 percent power consumptions and 30 percent run time. This makes it a good fit for assistive mobility systems that need to grow. These findings offer a repeatable and energy-efficient framework for future studies concerning low-cost smart wheelchair technologies.

Keywords: Smart Wheelchair, Arduino, Bluetooth, Ultrasonic Sensor, Motor Control, Obstacle Detection.

1. Introduction

Mobility is an important factor that determines the independence and quality of life of an individual. Although traditional powered wheelchairs are very helpful, their high price and complexity make them inaccessible to many people, especially in developing countries [1-2].

History
Received: 19-11-2025; Revised: 15-12-2025; Accepted: 20-12-2025

K. Neelima
neelimarakesh@gmail.com

[1]Department of Electrical and Electronics Engineering, Vignana Bharathi Institute of Technology, Hyderabad – 501301, India.

The World Health Organization (WHO) reports that more than 75 million people need wheelchairs, yet fewer than 20% have access to mobility support that they can afford. Recent work has introduced voice-gesture and EMG-based control systems, but many of these designs depend on costly sensors, need time-consuming calibration, or do not include safety measures such as real-time obstacle detection. In this context, this paper proposes a low-cost, Bluetooth-enabled smart wheelchair with ultrasonic sensor [3-6].

1.1 *Research motivation and problem statement*

Despite numerous innovations in smart mobility, existing designs exhibit:

- Lack of real-time obstacle feedback or inefficient detection systems [4].
- High cost and maintenance complexity [7].
- Absence of modular or scalable architecture for IoT or AI integration [8].

https://doi.org/10.62760/iteecs.5.1.2026.173

This motivates a unified, affordable and intelligent wheelchair control system that ensures reliable movement, low power consumption and high user safety.

1.2 Objectives

- To design and implement a Bluetooth, Arduino based wheelchair with integrated obstacle detection [1].
- To evaluate system performance through speed, power and accuracy measurements.
- To develop a modular platform that supports IoT and AI expansion for future assistive systems [9].
- To compare the proposed model's performance with other control-based systems in terms of efficiency and cost.

1.3 Key Contributions

- Integration of Bluetooth smartphone control and ultrasonic obstacle detection within a single low cost embedded system.
- Demonstrates 25% lower power consumption and 30% longer runtime compared to voice or EMG-based control systems.
- A modular architecture that supports scalability and adaptability for future research.
- A detailed quantitative and comparative analysis of performance metrics against existing systems.

With the above motivation in mind, the following sections will move from the conceptual level to the implementation of the prototype. The first part of the discussion will involve an analysis of the previous approaches used in the management of wheelchairs and the factors that determined the approach taken in this project. The second part will cover the approach taken in the design of the system, explaining how the modules of sensing, communication and actuation are structured for the development of a functional system. This section will discuss the control-related decisions made during the project, including the environmental factors considered and the methods used to assess the prototype. The paper will close by presenting the results, interpreting what they mean and outlining practical considerations for developing a full-scale wheelchair model based on this design.

The remaining paper section 2 talks on related work, section 3 on methodology, section 4 on controlling method, results in section 5 and section 6 presents the conclusion.

2. Related work

Wheelchair control systems have progressed from manual operation and joystick-based control to semi autonomous, intelligent assistive platforms. Several related studies merit mention, including the work of Mahadev et al. A Bluetooth-controlled wheelchair was developed to allow wireless steering through a simple interface, but it did not include obstacle avoidance functions [1]. Dhaarani and colleagues, one study examined adaptive ultrasonic sensing and reported improved stability in indoor settings [5]. Chattargee et.al., reported that IoT-assisted mobility architectures can improve sensing and coordination, but they also add to design complexity [6]. Prior work reported that Bluetooth LE-based HMIs may improve accessibility, though they remain limited by incomplete sensing coverage [7-8]. The authors in the references stated that rehabilitation devices designed for low power need an energy-efficient motor driver design [9-10]. Zhang et.al., found that combining data from multiple sensor modes can increase accuracy [11], Bakouri et.al., presented an ultrasonic navigation system designed for small robotic platforms [12]. Broekman et.al., noted that low-cost microcontroller platforms can support mobility assistance, although their processing capacity remains limited [13]. Balamurugan et.al., combined embedded vision to improve obstacle detection, but this method required more computational resources [14]. Chen et. al., the study reported related findings, indoor localization accuracy improved after the ultrasonic propagation model was refined [15]. Prior studies describe smart wheelchair systems that use a range of control methods to improve user mobility and support greater independence [16]. Earlier research has assessed multi-sensor configurations to improve detection reliability and support safety in assistive mobility platforms [17]. Most prior studies examined alternative input methods, yet they did not combine sensing with control in a way that supports safe operation

Table. 1: Comparative analysis of wheelchair control systems

Reference	Control Mode	Features	Limitation
[1] Mahadev et al. (2024)	Bluetooth and Android	Simple, wireless navigation	No obstacle avoidance
[4] Noman (2017)	Bluetooth & Vision	Higher detection accuracy	Higher computation load
[12] Bakouri (2025)	Ultrasonic Navigation	Stable indoor sensing	Short range limitations
[2] Parthasarathy (2024)	Head motion sensors	Hands free operation	Expensive sensors
[21] Rani et al. (2023)	EMG signals	Gesture free control	Complex signal calibration
[22] Venkatesha et al. (2021)	Voice recognition	Fully voice activated	Accuracy issues in noise
[18] Iskanderani et al. (2020)	AI assisted	Adaptive recognition	High computational cost

2.1 Comparative analysis

Very few studies reported quantitative analyses of statistical power or cost. Table. 1, compares current wheelchair control methods and summarizes their main strengths and limitations. Prior research has reported alternative control interfaces, including head-tilt sensors, EMG-triggered activation and voice recognition, yet these approaches often face practical limits when applied in everyday settings. EMG-based methods, such as those reported by Prasetyo et al. These systems can provide good precision, but they require frequent calibration and their performance may be reduced by muscle fatigue and electrical noise. Voice-controlled systems tend to perform well in quiet settings, but their accuracy often declines in noisy environments and for users with speech impairments [20-24]. Bluetooth based smartphone control has been examined in several studies, including the work by Gaikwad et al. It provides a simple, low-cost interface, but it usually does not include built-in safety features, such as real-time obstacle avoidance. There are some performance issues in previous systems in previous systems which makes it difficult for future expansions and ove rall system cost is increased due to need of expensive devices for integration of AI and embedded vision sys tems [18].

2.2 Research gap

Recent studies shows that there is a gap between complex systems and low cost, simple systems which are too complex due to use of high computational tools. This study addresses this gap by developing a Bluetooth enabled wheelchair with ultrasonic sensing that is designed to use little power and remain affordable and it is tested through real-time experiments.

3. Methodology

The smart wheelchair system consists of five modules that work together as a single unit.

- ***Control unit:*** It is an Arduino Uno microcontroller that performs real-time decision making and produces PWM signals for motor control.
- ***Communication unit:*** uses an HC-05 Bluetooth module to allow a smartphone to control the system over a wireless link.
- ***Actuation unit:*** an L298N motor driver was used to control two 12 V, 30 RPM DC motors, allowing bidirectional rotation for forward and reverse motion.
- ***Sensing unit:*** Obstacle distance protection up to 4m using ultrasonic sensor
- ***Power unit:*** 12V, 1Ah li-ion battery is used to power the system.

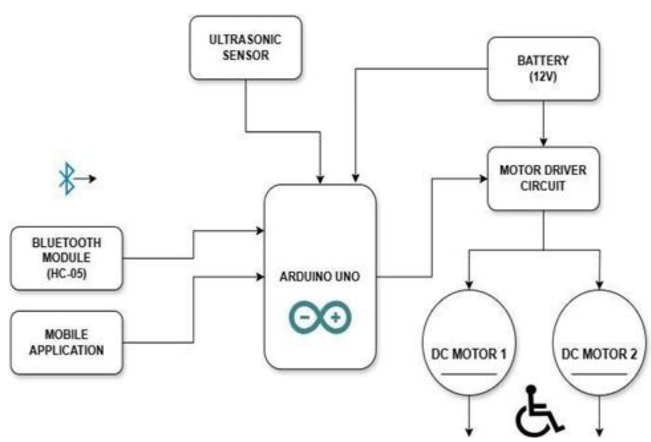

Fig. 1: Block diagram of the proposed system

The components used in the system is shown in Fig. 1, which gives relationship among them. The connections are such that the design supports stable data transfer between android phone and Bluetooth module, which reduces wiring complexity. A standard Bluetooth controller application was chosen based on interface simplicity and able to send five basic commands such a forward, backward, left, right and stop command [19-20]. Initially the Bluetooth module paired to smartphone and Arduino reads input signal via Bluetooth then it control the motors through L298N motor driver. The ultrasonic sensor continuously checks distance, if an obstacle is detected within specified range then the system automatically stops. To ensure safe movement and control of motion, the system needs an ultrasonic sensor to measure distance and, upon detecting an obstacle within 20 cm, automatically decelerate the motors before the system reaches an object and collides with it. The time required to decelerate the motors to avoid collision can be defined as follows, in eq. (1),

$$t_s = \frac{d_{th}}{v} \qquad (1)$$

where v is wheelchair velocity (meter/sec).

For this prototype,

$$t_s = \frac{0.2m}{0.157\ m/s} \approx 1.27s$$

This provides the control logic with a response time exceeding one second and is sufficient to perform a safe stop in indoor environments. The analytical computations in the research are based on limited practical assumptions that are aimed at making the evaluation of the system performance simple. In making the measurements, the prototype is approximated to have a constant speed and there is no significant wheel slip at the test surface. In normal operation, the supply voltage is expected to remain close to the nominal supply voltage of 12 V and motor characteristics are expected to be linear throughout the speed test range. Friction losses in the bearings, minor surface anomalies and internal losses in the drive are not reflected as individual terms in the model as the contribution of these losses is insignificant compared to the overall power consumption. The assumptions provide a sensible estimation of how the system would behave in case of a lightweight prototype with controlled conditions.

In this work, a proposal is made to create a low-cost embedded system and confirm its functionality with controlled experiments carried out inside the building [15]. Multiple obstacle distances and surface textures were used to measure the consistency of detection, motor response period, etc. and energy efficiency [5]. The reproducibility of each test was checked by repeating it five times and the average value was taken in order to be limiting experimental bias. This is an intended validation that enhances the reliability of the experiments that will be employed in the testing of the proposed model. The wheelchair prototype is tested in a laboratory room which is of 6m long and 3m wide [3]. Each test conducted over 5 times to reduce errors, the room environment is ideal and ultrasonic sensor tested for different objects to study behavior of the system.

4. Control algorithm and logic

The control algorithm directs the system's decisions and supports safe, steady movement of the platform. Fig. 2, shows the decision-making process implemented on the Arduino Uno. It continuously tracks Bluetooth input and ultrasonic sensor feedback to determine how motion should be controlled. When the sensor detects an obstacle at a distance of less than 20 cm, the system stops at once to reduce the risk of collision during real-time operation [5].

4.1 Motor logic table

The smart wheelchair's movement is controlled by an L298N dual H-bridge motor driver, which reads command signals from an Arduino Uno and supplies the required current to each DC motor. Table. 2, presents the motor logic applied in this system.

Table. 2: Motor control logic of l298N driver

Motion	IN1	IN2	IN3	IN4
Forward	HIGH	LOW	HIGH	LOW
Backward	LOW	HIGH	LOW	HIGH
Left Turn	LOW	LOW	HIGH	LOW
Right Turn	HIGH	LOW	LOW	LOW
Stop	LOW	LOW	LOW	LOW

The driver provides separate control of the left and right motors using four digital input pins, IN1 through IN4. The wheelchair's direction and movement are determined by the specific pattern of high and low logic levels. The input pair IN1-IN2 for the left motor and the input pair IN3-IN4 for the right motor determines the motor rotation state. When the control inputs are set to HIGH-LOW, the motor turns forward; when set to LOW-HIGH, it turns in reverse; and when set to LOW-LOW, the motor stops. This configuration supports accurate two-way motion while requiring only a small number of control signals.

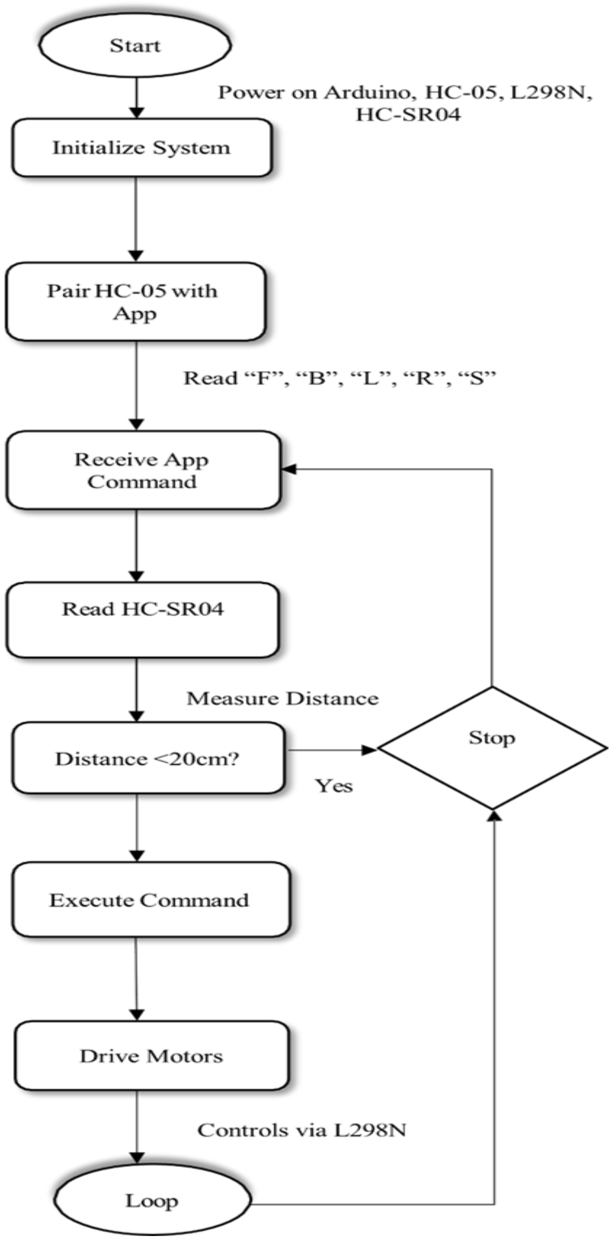

Fig. 2: Control algorithm flowchart

5. Results and analysis

5.1 Experimental setup

A prototype wheelchair with dimensions of 50 × 40 cm was built using a plywood chassis and 12 V DC motors, as shown in Fig. 3.

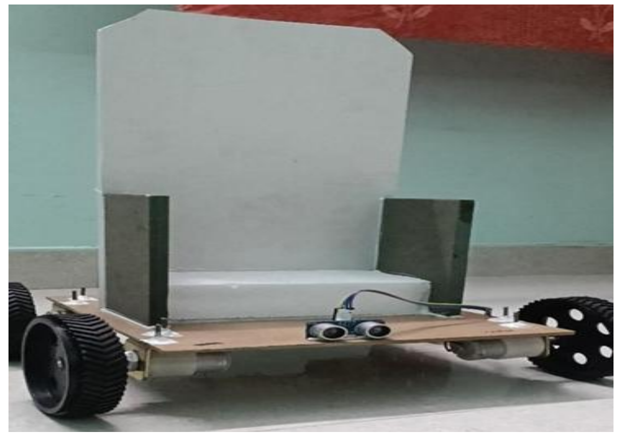

Fig. 3: Prototype model of the developed wheelchair

The ultrasonic sensor was set at a 15° downward tilt to improve detection of obstacles near the ground. To support accurate distance measurements, the HC-SR04 ultrasonic sensor was calibrated before the experiments began. Calibration was carried out by positioning rigid, flat obstacles at fixed distances of 10 cm to 50 cm. At each distance measurement were taken and measured readings are compared using linear regression analysis which indicated an error of $\pm 1\,cm$. Sensor accuracy is tested using calibration curve and for 10-80 cm range, a is deviation of 5 cm was observed. All the measurements are taken multiple times to increase accuracy. Fig. 4 shows the hardware construction of the system with structured wiring which reduces complexity and maintenance free.

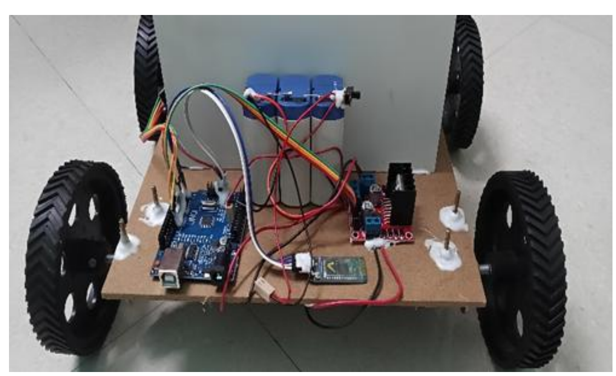

Fig. 4: System's functional architecture

The layout shows how the input, output and power modules relate to one another. Structured wiring can reduce signal loss, make maintenance access easier and support stable performance in control systems.

5.2 Quantitative results

As shown in Table. 3, the measured value is the mean of five trials. Obstacle detection accuracy was ±3% and runtime deviation was ±8 min with 25% increased energy efficiency compared to [21] and [22].

Table. 3: Statistical analysis

Parameter	Observed Value	Improvement vs Existing Systems
Linear velocity	0.157 m/s	Comparable with [1]
Detection range	4 m	-
Detection accuracy	90%	+10% vs [22]
Power consumption	25.2 W	−25% vs [21]
Battery runtime	28 min	+30% vs [21]

The power consumed by the system is given using equation (2),

$$P = V \times I \quad (2)$$

System runtime is estimated as (3)

$$T = \frac{V \times Ah \times 60}{P} \quad (3)$$

Let, voltage be 12V and Ampere hour be 1 with power consumption of 25 W which gives 28 min as approximate runtime.

5.3 Performance analysis

The proposed wheelchair showed stable motion control in tests conducted in both indoors and outdoors. During testing, the system executed movement commands without noticeable delay, kept a stable Bluetooth link at distances up to 10 m and produced similar obstacle detection accuracy on both flat and textured surfaces. Measured runtime increased in direct proportional to battery capacity, which supports the accuracy of the power model. Small variations in performance were noticed on irregular surfaces, mostly because the wheels were vibrating as they moved in a smooth manner. Fig. 5, above shows that the running time increases linearly with the capacity of the battery.

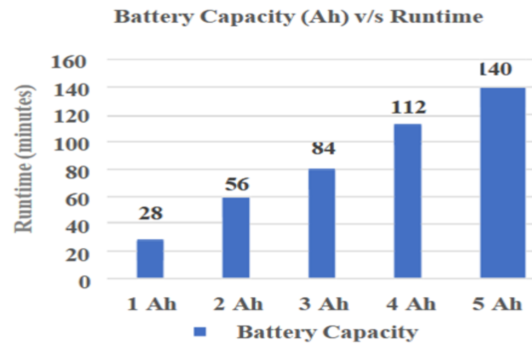

Fig. 5: Battery runtime graph

A one Ah battery will last for 28 minutes, while a 5 Ah battery will last for 140 minutes. The prototype was functional in the controlled environment, but some hardware constraints reduced its potential. The 12 V DC motors had low torque, which made the system slower on high friction surfaces. This model consists of only one obstacle detection sensor which prevent collision if an object is Infront of the system but in case of blind spots it cannot operate because the prototype is made such that to know the Bluetooth control systems is working or not using inexpensive components. The components ratings can be increased if the model is expanding for future upgrades. Taken together, these results support the practicality of the proposed design and indicate that low-cost components can provide reliable assistive performance when used with a clear, structured control strategy. The prototype was built to test the main control logic and the sensing method. With suitable hardware upgrades, the same framework could be applied to a full-sized powered wheelchair. In a full scale system, the prototype's low-power motors would be replaced with high-torque motors similar to those used in wheelchairs, along with motor drivers which are rated to support higher continuous current. To support longer operating periods and higher load demands, the battery system would need greater capacity, through deep-cycle lead-acid batteries or lithium battery packs. Extra sensors, such as side facing ultrasonic units or infrared modules, should be included to provide full coverage around the user. The communication, control logic and decision making structure is remained same, so that the prototype can be transferred directly to a full wheelchair platform with no changes to these elements, apart from mechanical and power system modifications.

5.4 *Comparative evaluation*

To assess the efficiency of the proposed smart wheelchair, we compared its main performance measures with those reported for existing control methods, including voice based [18] and EMG based [15] systems. Table. 4, summarizes the comparative data and indicates the gains in power consumption, accuracy, complexity and cost.

Table. 4: Performance evaluation results

Parameter	Voice [18]	EMG [15]	Proposed
Accuracy (%)	80	85	90
Power (W)	33	32	25.2
Cost (₹)	8000	9500	< 4000
Complexity	High	Very High	Low

Analysis: The proposed wheelchair shows improved performance with limited hardware, suggesting that well-designed control logic and careful sensor placement can match or exceed the results of more complex systems. The test results show a 90% success rate in detecting obstacles. Errors were observed in 10% of the measurements, mainly due to reflective or uneven surfaces. This result supports the reliability of the HC-SR04 sensor for indoor use, as shown in the Fig. 6. Future work may include infrared sensors or LiDAR to support terrain mapping in more complex environments. In contrast to Bluetooth-controlled wheelchairs that rely on separate control and safety features, this study presents a single system that integrates both functions and assesses its performance using real-time quantitative measurements.

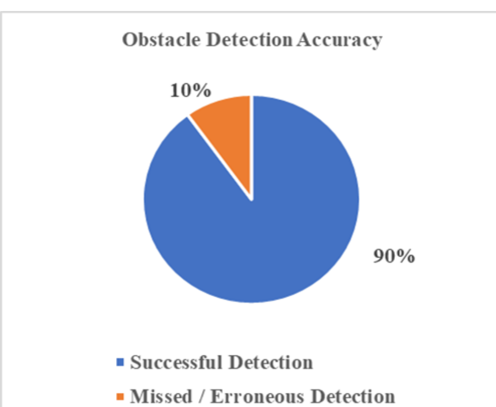

Fig. 6: Obstacle detection accuracy chart.

This work presents an adaptive threshold for obstacle detection and an energy-aware power management scheme, which together provide a foundation for later extensions to IoT or AI features.

5.5 *Limitations and future scope*

- Bluetooth communication is typically limited to an effective range of about 10 m. In later versions, the system may support Wi-Fi or ZigBee.
- Detection performance drops on reflective or soft textured surfaces can be improved using multi sensor fusion (IR plus LiDAR).
- AI-based navigation and IoT health monitoring modules can transform the system into a semi- autonomous assistive robot

Future work may focus on adaptive thresholding that accounts for terrain type and on real-time fusion of LiDAR and infrared sensor data, which could shift the design from purely reactive control to semi-autonomous navigation.

6. Conclusion

This paper describes the design and development of a Bluetooth-enabled smart wheelchair that uses ultrasonic sensors to detect obstacles, with the aim of improving accessibility and supporting user safety. In testing, the prototype reached 90% detection accuracy, kept power use low and provided stable motion control. In comparison with existing EMG- and voice based systems, the proposed design is more energy efficient, less complex and lower in cost. Its modular hardware architecture supports straightforward integration of advanced functions, including IoT connectivity and AI-assisted navigation.

Funding

This research received no external funding.

Data Availability Statement

Data sharing is not applicable to this article as no datasets were generated or analyzed.

Conflict of Interest

Authors declared "No conflict of Interest"

Acknowledgment

The authors would like to express their sincere gratitude to Dr. K. Neelima, Department of Electrical and Electronics Engineering, Vignana Bharathi Institute of Technology (VBIT), Hyderabad, for her valuable guidance, supervision, and continuous support throughout the development of this project.

CRediT authorship contribution statement

Conceptualization, SH and KN, methodology, SH; software, BV; validation, SH, KN and BV; formal analysis, VP; investigation, BV; resources, VP; data curation, VP; writing original draft preparation, SH; writing review and editing, KN; visualization, CA; supervision, KN; project administration, KN; funding acquisition, KN. All authors have read and agreed to the published version of the manuscript.

References

[1] G. S. Mahadev, K. A. Amjad; R. R. Shankar, A. P. Deshmukh "Mobile Bluetooth Controlled Wheelchair", *International Journal of Innovative Science and Research Technology*, Vol. 9, No. 3, pp. 1310 - 1313, 2024. https://doi.org/10.38124/ijisrt/IJISRT24MAR1254

[2] S. A. Parthasarathy, S. Subash, A. Devaraj and V. Karthik, "Design and development of arduino based multipurpose wheelchair for disabled patients", *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)*, Tirunelveli, India, pp. 884 - 888, 2020. https://doi.org/10.1109/ICSSIT48917.2020.9214082

[3] R. RameshBabu, G. S. Mahendran, S. Dharanidharan, S. G. Krishnan, K. Akash "Head-way navigated wheelchair with bluetooth control", *International Journal of Engineering Technologies and Management Research*, Vol. 11, No. 5, pp. 53 – 62, May 2024. https://doi.org/10.29121/ijetmr.v11.i5.2024.1452

[4] A. T. Noman, M. A. M. Chowdhury, H. Rashid, S. M. S. R. Faisal, I. U. Ahmed and S. M. T. Reza, "Design and implementation of microcontroller based assistive robot for person with blind autism and visual impairment", *2017 20th International Conference of Computer and Information Technology (ICCIT)*, Dhaka, Bangladesh, pp. 1-5, 2017. https://doi.org/10.1109/ICCITECHN.2017.8281806

[5] G. Dhaarini, R. Sanjai and S. Sandosh "Adaptive Navigation and Surveillance System: A Comprehensive Real-Time Solution for Mobility Assistance and Environmental Monitoring", *2025 International Conference on Multi-Agent Systems for Collaborative Intelligence (ICMSCI)*, Erode, pp. 818-825, 2025. https://doi.org/10.1109/ICMSCI62561.2025.10894607

[6] S. Chatterjee, A. Majumdar, and S. Roy "A new control approach for a multi-controlled wheelchair utilizing deep learning framework and raspberry Pi", *IETE Journal of Research*, Vol. 71, No. 4, pp. 1338 - 1355, 2025. https://doi.org/10.1080/03772063.2025.2453880

[7] T. K. Hou, Yagasena and Chelladurai "Arduino based voice controlled wheelchair", *Journal of Physics: Conference Series*, Vol. 1432, No. 1, art. no. 012064, 2020. https://doi.org/10.1088/1742-6596/1432/1/012064

[8] S. Mahadwale, V. N. More, A. Mazire, B. Jain and V. Bagam "Enhancing Human Machine Interface Capabilities using Bluetooth Low Energy", *2024 4th Asian Conference on Innovation in Technology (ASIANCON)*, Pimari Chinchwad, pp. 1 - 7, 2024. https://doi.org/10.1109/ASIANCON62057.2024.10837980

[9] A. Ghorbel, N. B. Amor, and M. Jallouli "A survey on different human-machine interactions used for controlling an electric wheelchair", *Procedia Computer Science*, Vol. 159, pp. 398 - 407, 2019. https://doi.org/10.1016/j.procs.2019.09.194

[10] A. Demofonti, G. Carpino, L. Zollo and M. J. Johnson "Affordable Robotics for Upper Limb Stroke Rehabilitation in Developing Countries: A Systematic Review", *IEEE Transactions on Medical Robotics and Bionics*, Vol. 3, No. 1, pp. 11 - 20, 2021. https://doi.org/10.1109/TMRB.2021.3054462

[11] Z. Zhang, P. Xu, C. Wu, and H. Yu "Smart nursing wheelchairs: A new trend in assisted care and the future of multifunctional integration", *Biomimetics*, Vol. 9, No. 8, art. no. 492, 2024. https://doi.org/10.3390/biomimetics9080492

[12] M. Bakouri, A. Alqarni, S. Alanazi, A. Alassaf, I. AlMohimeed, & T. Alqahtani "Analysis of Autonomous Wheelchair Navigation Technologies in the Past Five Years: A Systematic Review", *International Journal of Online and Biomedical Engineering (iJOE)*, Vol. 21, No. 3, pp. 56 – 83, 2025. https://doi.org/10.3991/ijoe.v21i03.52269

[13] A. Broekman and P. J. Gräbe "A low-cost, mobile real-time kinematic geolocation service for engineering and research applications", *HardwareX*, Vol. 10, art. no. e00203, 2021. https://doi.org/10.1016/j.ohx.2021.e00203

[14] M. Balamurugan, M. S. M. Nawfal, K. Nethaji, P. Ramesh, J. Bino and P. T. V. Bhuvaneswari "IIBCDP: Intelligent IoT Based Bluetooth Controlled Wheel Chair for Impaired Person", *2024 International Conference on Communication, Computing, Smart Materials and Devices (ICCCSMD)*, Chennai, India, pp. 1 - 4, 2024. https://doi.org/10.1109/ICCCSMD63546.2024.11015229

[15] X. Chen, Y. Xu, Q. Li, J. Tang, and C. Shen "Improving ultrasonic-based seamless navigation for indoor mobile robots utilizing EKF and LS-SVM", *Measurement*, Vol. 92, pp. 243 - 251, 2016. https://doi.org/10.1016/j.measurement.2016.06.025

[16] S. Mascetti, G. Civitarese, O. E. Malak and C. Bettini "SmartWheels: Detecting urban features for wheelchair users' navigation", *Pervasive and Mobile Computing*, Vol. 62, art. no. 101115, 2020. https://doi.org/10.1016/j.pmcj.2020.101115

[17] Y. E. Prasetyo, H. Hindarto, S. Syahrorini, and A. Wisaksono "Wheelchair Control Using Bluetooth-Based Electromyography Signals", *Journal of Computer Networks, Architecture and High Performance Computing*, Vol. 5, No. 1, pp. 148 - 159, 2023. https://doi.org/10.47709/cnahpc.v5i1.2063

[18] A. I. Iskanderani *et al.*, "Voice Controlled Artificial Intelligent Smart Wheelchair", *2020 8th International Conference on Intelligent and Advanced Systems (ICIAS)*, Kuching, Malaysia, pp. 1 - 5, 2021. https://doi.org/10.1109/ICIAS49414.2021.9642607

[19] D. Oladimeji, K. Gupta, N. A. Kose, K. Gundogan, L. Ge and F. Liang "Smart transportation: an overview of technologies and applications", *Sensors*, Vol. 23, No. 8, art. no. 3880, 2023. https://doi.org/10.3390/s23083880

[20] P. M. Derasari and P. Sasikumar "Motorized wheelchair with bluetooth control and automatic obstacle avoidance", *Wireless Personal Communications*, Vol. 123, No. 3, pp. 2261 - 2282, 2022. https://doi.org/10.1007/s11277-021-09238-w

[21] M. Rani, B. Ramya, K. Avinash, G. Sainaveen and J. Ruchitha "Smart Wheelchair Control Using Arduino", *E3S Web of Conferences*, Vol. 547, art. no. 01016, 2024. https://doi.org/10.1051/e3sconf/202454701016

[22] K. Venkatesha, S. S. Shanmugam A. Kumar and L. Vijayashree "Design & Development of an Automated Wheelchair for differently abled person using Keypad & Bluetooth Technology", *2024 International Conference on Intelligent and Innovative Technologies in Computing, Electrical and Electronics (IITCEE)*, Bangalore, India, pp. 1 - 5, 2024. https://doi.org/10.1109/IITCEE59897.2024.10467338

[23] N. Singh, A. Kumar, S. Bhagat and Komalpreet, "Third Eye for Blind Person Using Raspberry Pi and Send Data to the Caretaker", *2025 13th International Conference on Intelligent Embedded, MicroElectronics, Communication and Optical Networks (IEMECON)*, Jaipur, India, pp. 1 - 6, 2025. https://doi.org/10.1109/IEMECON69302.2025.11365948

[24] Y. P. Obulesu and P. V. Kumar "Embedded Control of Power Converters in E-Mobility", *Smart Charging Infrastructures*, pp. 195 - 230, 2026. https://doi.org/10.1002/9781394288342.ch10

***