World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(Research Article)

Check for updates

Design and development of an Affordable Sinhala Language-Enabled Voice-Assisted Smart Wheelchair

Samodhi Premarathna *, Harsha Madushan, Siva Uthayaraj, Sundaresh Jeyaram and Rajan Vinojan

Department of Physical Science, Faculty of Applied Science, Trincomalee Campus, Eastern University, Sri Lanka, Nilaveli, 31010, Trincomalee, Sri Lanka.

World Journal of Advanced Engineering Technology and Sciences, 2026, 18(03), 437-441

Publication history: Received on 03 February 2026; revised on 18 March 2026; accepted on 20 March 2026

Article DOI: https://doi.org/10.30574/wjaets.2026.18.3.0161

Abstract

Assistive mobility technologies have undergone significant advancements with the integration of embedded systems, speech recognition, and intelligent control mechanisms. However, commercially available voice-assisted smart wheelchairs predominantly support English and a limited set of widely spoken international languages, thereby restricting accessibility for native language speakers and remaining financially inaccessible to many users in developing countries. In Sri Lanka, where Sinhala is the primary language of communication for the majority of the population, this linguistic limitation presents a significant barrier to independent assistive mobility.

This study presents the design and development of a Sinhala Language-Enabled Voice-Assisted Smart Wheelchair (VASW), tailored specifically to the linguistic, economic, and technological context of Sri Lanka. The proposed system integrates an Arduino Uno-based embedded control architecture, dual 12 V DC motors for propulsion, ultrasonic sensors for obstacle detection, a microphone module for voice acquisition, and a micro-SD storage module for command processing.

Direction-specific Sinhala commands corresponding to forward, backward, left, right, and stop are trained and processed locally without reliance on external smartphone applications or cloud-based platforms. The voice recognition module provides an approximate response latency of 10 ms, enabling near real-time operation.

The architecture prioritizes affordability, modularity, and reduced system complexity while ensuring functional reliability. Experimental validation conducted in controlled indoor environments demonstrates accurate command recognition and safe maneuverability within predefined operational constraints. The proposed system offers a linguistically localized, economically feasible assistive mobility solution tailored to the Sri Lankan context.

Furthermore, a scalable framework for future integration of adaptive Artificial Intelligence (AI)-based speech processing is proposed to accommodate regional Sinhala dialect variations. The novelty of the system lies in its linguistic localization, economic accessibility, and modular design architecture. The proposed VASW contributes toward equitable assistive technology deployment in resource-constrained environments and establishes a foundation for language-inclusive mobility solutions.

Keywords: Voice-assisted wheelchair; Sinhala speech recognition; Assistive mobility; Embedded Systems; Microcontroller

* Corresponding author: S. Premarathna.

1. Introduction

Assistive technologies are fundamental in promoting independence and social participation among individuals with physical disabilities. Conventional manual wheelchairs require significant upper limb strength or continuous caregiver support, thereby limiting user autonomy. Although electrically powered and intelligent wheelchairs have been introduced to mitigate these limitations, such systems frequently remain financially prohibitive and technologically inaccessible in developing countries.

The evolution of wheelchair technology has progressed from purely manual systems to joystick controlled electric wheelchairs and subsequently to sensor assisted and intelligent navigation platforms [1]. Early electric wheelchairs relied primarily on joystick interfaces, which, although effective, remained unsuitable for users with severe upper limb impairments [2]. Subsequent innovations incorporated gesture control, head motion interfaces, eye tracking mechanisms, and multimodal sensor integration [3]. Despite their technological sophistication, these systems often require complex calibration procedures, advanced signal processing, and costly hardware components.

Voice-controlled wheelchairs have emerged as a natural and intuitive alternative, enabling directional navigation through spoken commands [4]. However, most existing systems are designed to recognize English or other widely spoken international languages. In multilingual societies such as Sri Lanka, where a significant proportion of the population communicates exclusively in Sinhala, such language restrictions significantly reduce usability. Furthermore, many implementations depend on smartphone-based applications or cloud processing platforms, thereby requiring additional internet connectivity, increasing system complexity and cost.

The motivation for this research emerged from direct observation of a wheelchair dependent individual who, due to upper limb amputation, remained fully dependent on caregiver assistance for mobility. Despite the availability of motorized wheelchairs internationally, the absence of Sinhala language support and high acquisition costs prevented adoption. This highlighted a fundamental technological and socioeconomic gap in the assistive device ecosystem of Sri Lanka.

1.1. Problem Statement

Three primary limitations are observed in existing voice-controlled wheelchair systems within the Sri Lankan context:

- Absence of Sinhala language support.
- Dependence on external smart devices or internet-based processing.
- High acquisition and maintenance costs unsuitable for low- and middle-income families.

These constraints restrict independent mobility among severely disabled individuals who are unable to operate manual wheelchairs and lack access to advanced imported systems.

Objectives

The primary objective of this research is to design and implement a standalone voice-controlled wheelchair capable of recognizing Sinhala language commands with low-cost embedded system architecture using readily available components. It also aims to establish a scalable framework for future integration of adaptive AI-based dialect recognition.

2. Materials and Methods

2.1. System Architecture

The overall system architecture comprises Voice Recognition and Acquisition Unit, Microcontroller-Based Control Unit, Motor Drive and Propulsion System, Obstacle Detection and Safety Module, and Power Management System, as illustrated in Figure 1.

In the operational workflow, spoken Sinhala commands are captured by the microphone embedded within the voice recognition module. Recognized commands are transmitted to the Arduino Uno microcontroller, which generates appropriate pulse-width modulation (PWM) signals for the motor driver. The motor driver subsequently controls the rotational direction and speed of the dual DC motors. Simultaneously, the ultrasonic sensor continuously monitors frontal obstacles to prevent collisions and enhance safety.

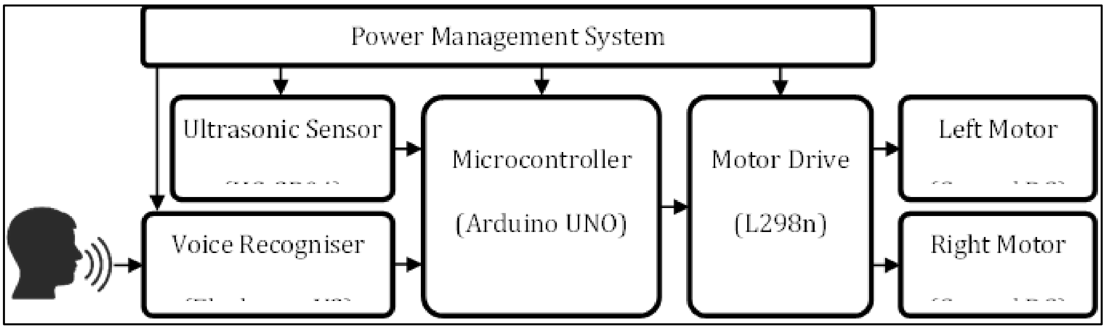

Figure 1 System Architecture

2.2. System Components

The ELECHOUSE Voice Recognition Module V3 was utilized as the primary speech processing interface. This module is Arduino-compatible and incorporates an onboard microphone for direct voice acquisition. The module is speaker-dependent and can store up to 80 voice commands, with seven commands accessible simultaneously during operation [5]. In the present implementation, Sinhala equivalents of directional commands forward, backward, left, right, and stop were trained and stored. The module exhibits a response time of approximately 10 ms, enabling near real-time execution of motor control instructions. Local processing eliminates dependence on internet connectivity and reduces computational overhead.

An Arduino UNO, based on the ATmega328P microcontroller, was employed as the central control unit. The microcontroller interprets recognized command signals and generates motor control outputs accordingly.

Two 30 W - 12 V DC geared motors were integrated to drive the primary wheelchair wheels. Differential drive control principles were applied to achieve forward, reverse, and turning maneuvers. Motor drivers were employed to regulate current supply and direction control. The propulsion system was designed to support a payload capacity of approximately 100 kg under standard operating conditions.

An ultrasonic sensor was incorporated to enhance operational safety [6]. The sensor operates by transmitting ultrasonic waves and measuring the time interval between emission and echo reception. Distance calculations are performed based on time-of-flight measurements. When an obstacle is detected within a predefined threshold distance, motor operation is automatically interrupted to prevent collision.

A 12 V rechargeable battery serves as the primary energy source. Voltage regulation circuits are implemented to provide a stable 5 V supply for control electronics and sensor modules.

The control process is executed sequentially starting from acquisition of spoken Sinhala command via microphone, then pattern matching within the trained voice recognition module, transmission of recognized command to Arduino Uno, generation of PWM signals to motor driver, and continuous obstacle monitoring and emergency stop override. The system operates as a closed-loop safety-aware navigation mechanism under supervised voice control.

3. Results and Discussion

Figure 2 illustrates the final design of the product. Experimental validation was conducted in an indoor environment under controlled acoustic conditions. The trained Sinhala commands were consistently recognized with minimal latency. Directional movement was observed to be accurate and responsive to issued commands.

Figure 2 Overall design of the System

The voice recognition module demonstrated reliable performance within its trained vocabulary set. Recognition latency was observed to be approximately 10 ms, enabling smooth real-time manoeuvring.

The ultrasonic sensor effectively detected frontal obstacles within the predefined range. Automatic interruption of motor operation was triggered upon threshold violation, thereby reducing collision risk. In controlled testing conditions, the integration of obstacle detection improved operational safety without introducing significant processing delays.

Compared to commercially available imported smart wheelchairs, the proposed system substantially reduces overall cost through the utilization of off-the-shelf Arduino-compatible components, by the elimination of smartphone or cloud dependency, and simplified standalone speech recognition architecture [4] [7]. This affordability enhances feasibility for low- and middle-income households in Sri Lanka.

Certain limitations were identified, such as speaker-dependent recognition which restricts multiuser adaptability. Environmental noise may affect recognition accuracy in non-ideal conditions. AI-based adaptive recognition remains under development. Noise reduction techniques and advanced filtering mechanisms may be incorporated in future iterations.

4. Conclusion

A more affordable Sinhala-Language-Enabled Voice-Assisted Smart Wheelchair has been successfully designed and implemented using a standalone voice recognition module, Arduino-based embedded control, dual DC motor propulsion, and ultrasonic obstacle detection. The system addresses both linguistic and economic barriers associated with existing voice-controlled mobility solutions.

Reliable recognition of trained Sinhala commands, low response latency, and effective obstacle detection were demonstrated under controlled conditions. The architecture provides a scalable foundation for IoT-enabled monitoring, AI-driven dialect adaptation, and multilingual expansion.

The proposed VASW represents a significant step toward inclusive, affordable, and locally contextualized assistive mobility technology in Sri Lanka and similar developing regions.

Compliance with ethical standards

Acknowledgments

We would like to express our sincere gratitude to the Department of Physical Science, Faculty of Applied Science, Trincomalee Campus, Eastern University, Sri Lanka for their invaluable support, including partial financial assistance and provision of laboratory facilities for this research project.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] R. C. Simpson, "Smart wheelchairs: A literature review", Journal of rehabilitation research and development, vol. 42, no. 4, pp. 423-36, 2005.

[2] D. Ding, R. A. Cooper, "Electric powered wheelchairs," IEEE Control Systems Magazine, vol. 25, no. 2, pp. 22-34, April 2005.

[3] A. Nair, A. Bhatkar, B. Biju, A. Shetty and M. Thomas, "Design and Development of a Smart Wheelchair," in 2021 4th Biennial International Conference on Nascent Technologies in Engineering (ICNTE), NaviMumbai, India, 2021.

[4] Priya C A, Saadiya, Bhagyashree, S D Pranjala, Mr Supreeth H S G, "Voice Controlled Wheelchair for Physically Disabled People," International Journal for Research in Applied Science & Engineering Technology (IJRASET), vol. 6, no. V, pp. 2375-2380, 2018, 05.

[5] Ibrahim S. Muhammad;Sanusi Mohammed;Aliyu M. Lawal;Dahiru Y. Gital, "Design and Development of Wheel Chair Using Voice Recognition for Physically Challenged Persons," "International Journal of Advances in Engineering and Management (IJAEM), vol. 6, pp. 315-320 , 09 Sep 2024.

[6] Arsha, M. and Raj, A. and Pooja, S. and Manoj, Rugma and Sabitha, S. and Mohan, Shimi, "Voice Controlled Wheelchair," International Journal of Research in Engineering, Science and Management, vol. 3, pp. 103-106, 09 2020.

[7] Hou, Tan and Appannah, Yagasena and Chelladurai, "Arduino based voice controlled wheelchair," Journal of Physics: Conference Series, vol. 1432, no. 1, p. 012064, 07 January 2020.