Design and Review of a Voice-Controlled Wheelchair

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***Abstract*: This paper presents the design of an Arduino-based automated wheelchair. The system is developed using a speech recognition module that enables physically disabled individuals particularly which those experiencing difficulty in hand movement due to ageing or paralysis-to control the wheelchair through voice commands instead of the conventional joystick-based operation. To ensure safe movement, the wheelchair is also equipped with an obstacle detection feature. The proposed system is implemented using an Arduino Mega 2560, an Easy-VR 3.0 speech recognition module, and relay-based motor controller circuits integrated with the wheelchair. Unlike several existing approaches that rely on wearable biomedical sensors which require complex signal processing and bulky external computing units-the designed system eliminates the need for such sensors. Compared to existing techniques, this system offers an affordable and practical solution, making it especially suitable for improving mobility assistance for physically disabled individuals in developing and underdeveloped countries. his review paper does not include experimental validation and focuses solely on analysis of existing research.**

***Keywords*: Voice Controlled Wheelchair, Assistive Technology, Speech Recognition, DC Motor Control, Arduino, Motor Driver, Battery Operated Wheelchair, Emergency Stop System**

I.INTRODUCTION

Physical mobility plays a vital role in enabling individuals to live independently and participate actively in society. People affected by conditions such as paralysis, polio, spinal cord injuries, or age-related disabilities often face significant challenges in moving from one place to another without assistance. For such individuals, wheelchairs serve as an essential mobility aid. However, conventional manual wheelchairs and joystick-operated electric wheelchairs require sufficient hand and arm movement, which may not be possible for users with severe motor impairments.

To overcome these limitations, assistive technologies have evolved to incorporate intelligent control mechanisms that reduce physical effort and enhance user autonomy. Among these technologies, wheelchairs have gained considerable attention due to their simplicity, affordability, and ease of use. By recognizing spoken commands, these systems allow users to control wheelchair movement without relying on hand-operated interfaces, thereby offering greater independence to individuals with limited upper-limb functionality.

Recent developments in embedded systems and speech recognition technology have made it possible to design compact and cost-effective voice-operated mobility solutions. Microcontrollers such as Arduino, combined with standalone speech recognition modules, enable reliable offline command processing without the need for complex signal processing or continuous internet connectivity. Additionally, the integration of obstacle detection sensors improves user safety by minimizing the risk of collisions during navigation.

This review paper presents an overview of wheelchair systems, focusing on their design methodologies, hardware components, and operational principles. Existing research contributions are analyzed to highlight their advantages, limitations, and practical challenges. The aim of this study is to provide a structured understanding of current developments in wheelchair technology and to identify potential directions for future improvements that can further enhance accessibility and reliability for physically challenged users.

II. OVERVIEW OF WHEELCHAIR SYSTEMS

A typical wheelchair consists of the following main components:

1. Speech recognition unit
2. Microcontroller or embedded processing unit

3. Motor driver and drive motors
4. Obstacle detection sensors
5. Power supply system

Voice commands are captured using a microphone, processed by a speech recognition module, and translated into control signals by a microcontroller. These signals are then used to drive the motors, enabling directional movement of the wheelchair.

Summary Research
Early wheelchair systems relied on simple keyword-based recognition or wired microphones. Modern systems employ dedicated speech recognition modules such as Easy-VR, ESP32-based processors, or cloud-based speech-to-text services. Offline speech recognition modules are particularly suitable for assistive devices as they do not depend on continuous internet connectivity and offer faster response times. Researchers have proposed noise filtering techniques and adaptive learning algorithms to enhance recognition performance.

III.OPERATION OF THE PROPOSED SYSTEM

This section describes the main parts of the developed automated wheelchair. Figure 1 shows the block diagram indicating the basic parts of the system.
The speech recognition block comprises three submodules: the Voice Capture Module, Voice Customization Module, and Voice Recognition Module, as depicted in Fig. 1 of our proposed system. The Voice Customization Module is utilized for training the system to recognize specific voice commands. In our case, we customize five commands FRONT, BACKWARD, RIGHT, LEFT, and STOP to direct the wheelchair's movement.

The working functions of the main parts of

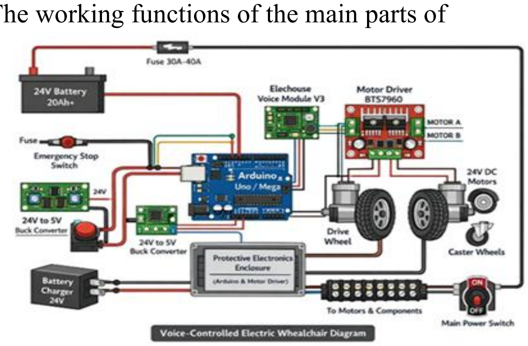

Fig. 1. Connection of the proposed system

The block diagram is described as below:
1. First, the audio or voice input is taken from the user and converted into electrical signal by the transducer. Then it is sent to the voice recognition device designed with Easy VR3 module and Arduino.
2. Commands used along with their explanations are mentioned below:

"Forward" will drive the wheelchair forward; "Right" or will turn the wheelchair right; "Left" will turn the wheelchair left; "Backward" will move the wheelchair in opposite direction; "Stop" command will stop the wheelchair from moving. The voice recognition device (i.e. Easy VR3) then processes the data and matches with the trained data and if the command matches then forwards a coded digital signal to the microcontroller.

III. Arduino Mega checks all the data coming from Easy VR3 and other ultrasonic sensors. If the voice commands are matched, then it sends an activation signal to the motor controller for controlling the motor movement to drive the wheelchair into desired direction.

IV.DEVICES AND SENSORS USED IN THE DESIGN

A. Voice Recognition Device: To design a small sized speech processor in comparison to the complex bulky signal processing system using laptop, we used EasyVR3 module as the stand-alone speech processor with Arduino. It is a compact device and also available as Arduino shield. It is compatible with any host device, which supports TTL logic level [12]. It has its own software, which is very user-friendly, easy to train and implement in real life application.

B. Microcontroller: In this design, we have used Arduino Mega2560, which is a modified form of ATMEL ATmega2560. To merge and use multiple devices together, Arduino Mega2560 was chosen which has 54 pins input/output pins, 4 UARTs, 16 analog inputs, a 16MHz oscillator. It has a Flash Memory 256 KB of which 8 KB used by bootloader, SRAM of 8 KB and EEPROM of 4 KB. It can be powered by an USB connection or with an external power supply. It contains everything needed to support the microcontroller.

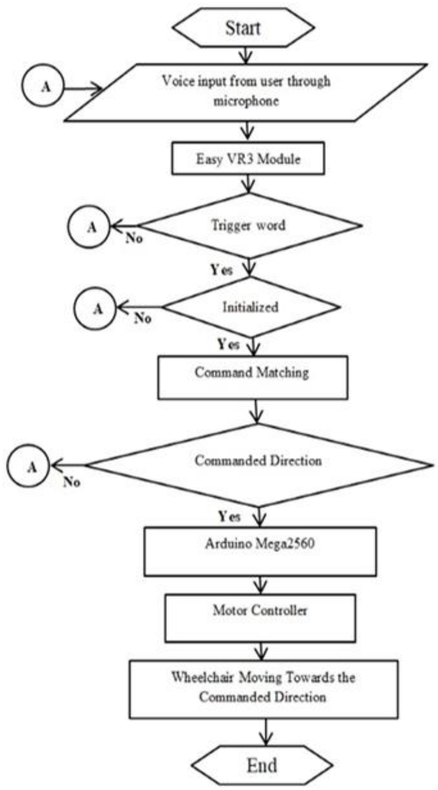

Fig.2. Operational Flow chart of the system. A is initial state of recording the command signal.

C. Motor: In this design, 24V 250watt brushed DC motor has been chosen as it is widely used in industrial applications where the load is heavy. The chosen motor's higher rotational speed measured in RPM can be reduced using gear mechanism to provide more starting torque. The motor has a starting torque of around 50Kg-cm operated at 12V.
When two motors rotate in same direction the wheelchair will move either in the forward or backward direction. For right directional movement, only left motors run in clockwise rotation and for the left directional movement only the right motor run in clockwise rotation. these rotational directions were checked by giving signals to the motor controller. DC-DC step-down buck converter was used to provide 5V for all the discrete electronic components and 12V for the relay from the main power source of 24V.

D. Motor Controller: A motor controller is needed to control its rotation so that the wheelchair can move toward the direction commanded by the use. Due to continuous heating issue of MOSFET driven motor controllers and considering the safety of the patient, we used 12V relay module as motor controller. Relay is an inductive device, which can store energy in its coils that can cause damage to low powered electronic components. Therefore, to protect the circuit, a freewheeling diode and an opto-coupler was used in the relay module so that it can be controlled by the low power microcontroller device.

E. Battery: Two 12V 30Ah (Ampere hour) sealed lead acid rechargeable batteries were used to provide power of the whole system. They were connected in series to have 24V to supply the power to the motor. Although this battery is little bit heavy weighted, this battery is used due to its availability and comparatively lower cost.

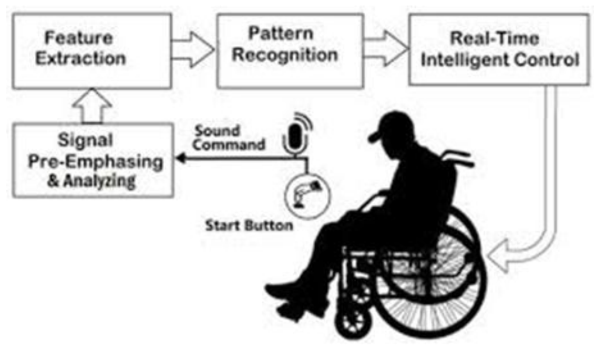

Fig3. Basic Structure of the wheelchair

wheelchairs enable users with severe mobility impairments, such as disabled person, to the navigate independently using spoken commands like "forward," "backward," "left," "right," and "stop." These systems typically integrate speech recognition modules (e.g., Google Cloud Speech-to-Text, Easy VR3, or ESP32-based processors), microcontrollers (Arduino or Raspberry Pi), and DC motors for propulsion. Ultrasonic and infrared sensors provide obstacle detection, enhancing safety by halting movement when barriers are detected. Early prototypes date back to patented designs from the 1990s, featuring throat microphones, backup excited-utterance commands for emergencies, and multi-mode operation to limit active commands for safety. Modern implementations build on Arduino UNO or ESP32 platforms, often tested at speeds around 0.2 m/s for users up to 80 kg, with evaluations showing high usability (average scores of 4.3-4.8 across metrics like reliability and comfort).
The Voice Control Wheelchair has the potential to

significantly improve the lives of individuals with mobility impairments or disabilities. The outcomes and impacts of this technology can be far-reaching and multifaceted:

- Increased Independence: Users can navigate their surroundings without relying on others, promoting autonomy and self-reliance.
- Improved Mobility: Voice control enables users to move around with greater ease, reducing fatigue and strain.
- Enhanced Safety: The voice control system can help prevent accidents by allowing users to quickly respond to changing environments.
- Increased Confidence: Users can regain confidence in their ability to navigate and participate in daily activities.
- Challenges & Limitations Speech Recognition Issues: Background noise and speech impairments can reduce accuracy.
- Battery & Power Consumption: systems may drain battery faster than manual ones.

Fig4. Internal structure of the wheelchair

Challenges persist, notably voice recognition errors in noisy environments, limited offline functionality, and poor support for non-English or accented speech. Dependency on clear articulation excludes users with speech impairments, while dynamic real-world settings (uneven terrain, crowds) reduce obstacle detection accuracy. High costs, maintenance needs, and power demands also hinder adoption, especially in developing regions.

The robotic wheelchair market, encompassing voice-enabled models, projects growth to USD 621.69 million by 2033 at a 12.56% CAGR, driven by smart integrations like augmented reality overlays and voice-activated home syncing. Electric wheelchair variants with voice controls are expected to reach USD 13.6 billion by 2035. Recent 2025 studies emphasize multi-modal controls (voice, joystick, app) for broader accessibility. Research trends focus on hybrid systems combining voice with gestures, AI-enhanced recognition for noisy settings, and haptic/auditory feedback. Pilot studies highlight intuitive interfaces reducing cognitive load, while systematic reviews (2017-2025) call for user-centered designs prioritizing offline reliability and local manufacturing.

Clinical evaluations validate prototypes but stress real-world robustness. Experimental evaluations reported in existing literature indicate that wheelchairs can perform reliably in controlled environments. However, studies consistently highlight reduced performance in noisy surroundings, emphasizing the need for improved speech processing and adaptive control techniques. Finally, we believe that those people who are socially isolated or lag behind due to their physical disability will have the opportunity to move freely without any assistance like other people of the society by using their voice commands.

V.CHALLENGES AND LIMITATIONS

Despite significant progress, wheelchair systems face several challenges:

- Reduced speech recognition accuracy in noisy surroundings
- Limited usability for users with speech impairments
- Higher power consumption compared to manual wheelchairs
- Maintenance and calibration requirements.

VI.CONCLUSION

This review paper presented a structured analysis and conceptual design overview of voice-controlled wheelchair systems. Such systems offer a promising solution for improving mobility and independence among individuals with severe physical disabilities. While existing technologies demonstrate effective functionality, further research is required to address challenges related to robustness, environmental noise, and inclusivity for users with speech impairments. Continued advancements in embedded systems and assistive technologies are expected to drive future innovation in intelligent wheelchair development.

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