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Design and Development of Solar-Powered, Voice-Automated and Gesture-Controlled Wheelchair with Obstacle Detection using Ultrasonic Sensor

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Abstract:- The present work aims to present an approach for assistive mobile technology—an intelligently engineered solar-powered wheelchair enriched with voice automation, obstacle detection, and gesture control facilitated by a gyro circuit and an RF transmitter. The integration of solar power ensures sustainability, allowing the wheelchair to operate efficiently on renewable energy. Voice automation provides users with seamless control, while obstacle detection mechanisms enhance safety by delivering precise responses to environmental challenges. The addition of gesture control, enabled by a gyro circuit, further augments user experience, allowing intuitive and hands-free navigation. The RF transmitter serves as a communication link, expanding the capabilities of the wheelchair by allowing users to remotely control and monitor it. This comprehensive wheelchair represents a pioneering step in assistive technology, combining sustainability, safety, and enhanced user interface to provide a holistic solution for individuals with physical disabilities.

***Keywords**:* Emergency navigation, Ultrasonic sensor, Battery charging using Solar, Motor, Micro-controller, CAD model, Arduino Nano, Command by means of Voice, Gesture Controlled, Switching mechanism , RF transmitter and receiver in wheelchair and Gloves, Prototype.

1. Introduction

In this paper, we tried to look at the comprehensive journey of the advancement of the smart wheelchair through the lens of the literature review in the domain. After the literature review, a consensus finding was aimed at the holistic inability of the wheelchair. While there were wheelchairs that assisted the physically challenged through voice assistance, and other auxiliary features, it failed to accommodate people who were mute. Therefore, alongside voice assistance and other important auxiliary features like solar charging and obstacle detection, we have tried to bridge the gap by integrating gesture control to enhance the accommodability of the wheelchair. The design of a voice-automated wheelchair equipped with ultrasonic sensors, Bluetooth model and solar power presents a versatile and innovative solution with a range of potential applications.

Here are different applications for such a wheelchair:

Personal Mobility Assistance: Individuals with mobility impairments, including those with paralysis or limited physical dexterity, can benefit from the wheelchair's voice automation and obstacle avoidance features, providing them with greater independence and ease of movement.

Healthcare Facilities: Hospitals and healthcare facilities can utilize these wheelchairs for patient transport within the premises. The voice-activated controls and obstacle avoidance capabilities contribute to efficient and safe patient transportation.

Assisted Living and Rehabilitation Centers: Assisted living facilities and rehabilitation centers can integrate these wheelchairs into their environments to assist residents and patients in moving around communal spaces independently.

Home Use for Elderly Individuals: Elderly individuals facing mobility challenges at home can use a wheelchair to navigate within their living spaces. The voice control simplifies operation, and the obstacle avoidance system enhances safety in home environments.

Outdoor Activities: The wheelchair's solar-powered feature makes it suitable for outdoor use. Individuals with mobility impairments can enjoy outdoor activities, such as strolls in parks or participation in outdoor events, with the assurance of sustainable energy.

Public Spaces and Events: Events, conferences, and public spaces can provide these wheelchairs for visitors with mobility needs, ensuring they can easily navigate through crowds and around event venues.

We have explained the System Configuration of the wheelchair. In this section, based on the literature review, we have explained the different features due to different components that can be integrated into the wheelchair. In the subsequent section, i.e., System Control (Proposed System), we have attempted to propose the optimal configuration to provide holistic facilities to provide a seamless user experience and high accommodability. Subsequently, we progress to conclude our findings. After studying the findings and the increasing need for technological advancement, we have proposed a future research scope section where we are trying to encourage the researchers to make strides toward the advancement in the domain of assistive mobility.

The motivation behind designing a voice-automated wheelchair equipped with ultrasonic sensors and powered by solar energy stems from a commitment to enhancing accessibility and independence for individuals with mobility challenges. This innovative wheelchair seeks to revolutionize the traditional concept of mobility assistance by incorporating cutting-edge technology.

2. Literature Review

The history of wheelchairs can be traced back to 5 century BC, and here we are, after so many years of design development, with the integration of advanced technology and innovations. The wheelchair is one of the most ubiquitous equipment that can be seen with people with lower limb disabilities. But to cater to the case of disability of both upper limb and lower limb, there are very few affordable options available in the market, and even the options that are available, the user is still dependent on some help. People with severe lower and upper disabilities have to resort to costly electronic-controlled wheelchairs or be dependent on another person to move them around in their manual wheelchairs. To solve that problem, the voice-automated wheelchair was designed in the late 1990s, when Researchers at the University of Toronto developed a voice-activated wheelchair prototype. This wheelchair used voice commands to perform basic movements such as forward, backward, left, and right. While rudimentary by today's standards, this innovation marked an important step in the development of voice-activated mobility devices.

It is now possible to use voice commands to control any electronics-based product thanks to advancements in speech recognition technology. To help people with both upper and lower limb problems, this technology is being used in voice-controlled wheelchairs.

The main components of an automated Wheelchairs are:

1) Voice recognition module

2) Microcontroller / Arduino

3) Motor controller

4) Gesture control using hand Gloves

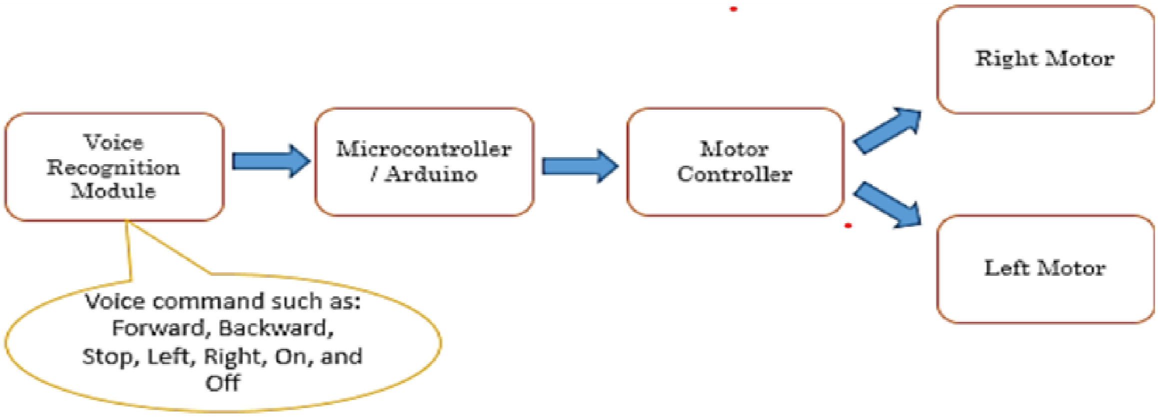

Fig 1- Components of an Automated Wheelchair

The main component of this project that is utilized to configure the appropriate voice command and output is the speech recognition module. Voice customization, voice capture, and voice recognition are the three stages of the process. Matching the desired recorded voice to the desired output signal is known as voice customization. Voice capture is the stage where the voice command of the target individual is recorded and saved by the customization setup. The next step is voice recognition, where when a voice command has been received, this module will transmit a specific signal to the microcontroller so that it may perform the required action.

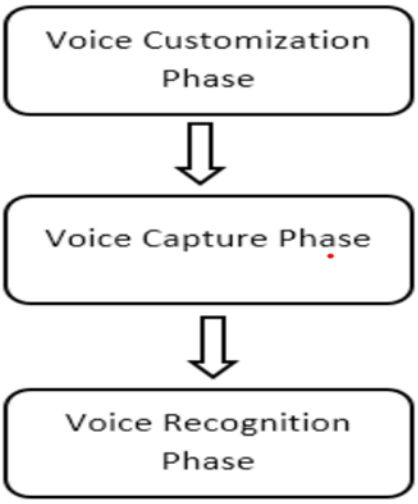

Fig 2- Speech Recognition Module

To capture the wheelchair's whole motion, the user must record a total of five (Babri & Malik, 2012) separate orders. The five voice commands used are *Forward, Backward, Turn Left, Turn Right, and Stop.* HC-05 Bluetooth module is used to transmit the voice command to the controller in a wireless manner. Thus, eliminating the need for a long and messy wiring nexus. (Sivakumar et al., 2013)

The main parts of the wheelchair are

1) Wireless communication (HC-05 Bluetooth module and Voice recognition module)

2) Main operation system (microcontroller, Gloves, motor drivers, and motors)

3) Sensor systems (ultrasonic sensors)

4) Gesture Control using Gloves.

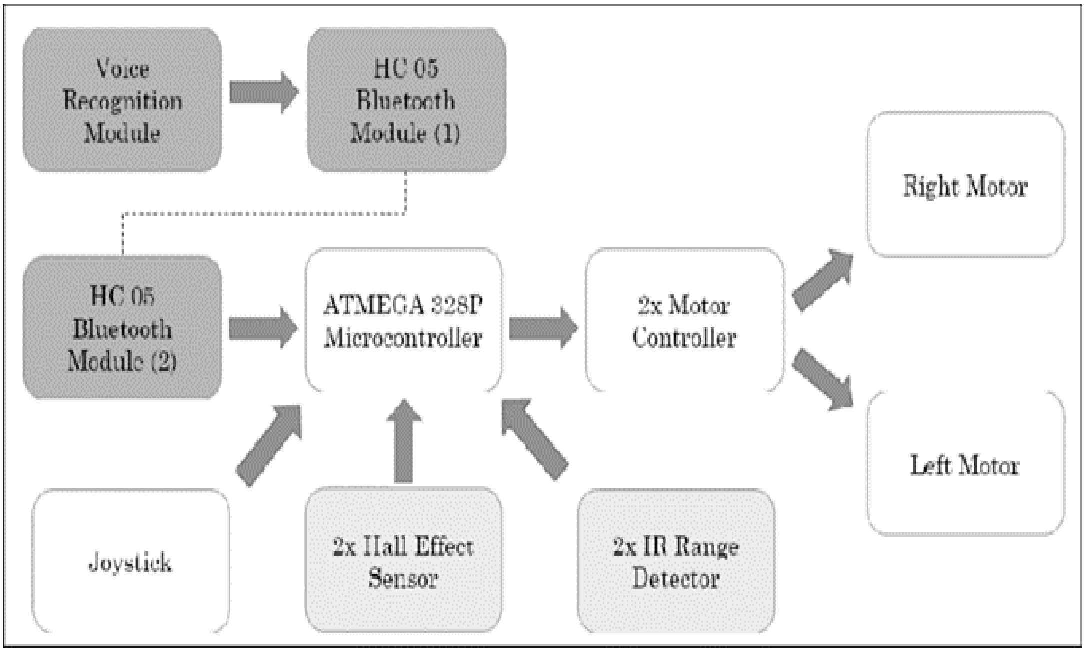

Fig 3- Main components of the Voice Automated Wheelchair

Despite the automation, and voice integration, an additional feature is needed to be added to the wheelchair which can sense the obstruction by itself if the user's response time is not adequate to stop the wheelchair or if the user is visually impaired. For this necessity, sensors are incorporated to detect some obstructions like a wall. For obstacle detection, Ultrasonic sensors with measurement ranges of 10 cm to 80 cm were fitted to both sides of the wheelchair. Since the DC brushed motor lacks speed control, two additional Hall Effect sensors were mounted on either side of the wheelchair to measure the speed of the wheel revolution. These sensors will track the wheel's rotation and provide feedback to the microcontroller so that speed may be stabilized.

3. Problem Statement

Accomplishing the design of Solar solar-powered, voice-automated Wheelchair equipped with ultrasonic sensors and gesture control enhancing user convenience for those who struggle with mobility challenges or have physical disabilities. While the traditional wheelchair fails in the market in terms of providing seamless and intelligent requirements of user experience, this model overcomes these problems ensuring the safety of users and enhancing the autonomy for them. The primary issue that remains in the market is the implementation of these advanced technologies into the conventional wheelchairs because of which it lacks independence and convenience for the diverse users. By incorporating these cutting-edge technologies like solar energy and the various sensors, and gesture controls, we aim to bridge this gap in the market and provide a user-friendly experience. This would lead the way to introducing a new assistive technology, prioritizing the quality of life of the users.

4. System Configuration

A. Voice Automation:

In the development of the voice-automated wheelchair, a cutting-edge voice recognition system has been seamlessly integrated, underscoring a commitment to user-friendly control and independent mobility. A reliable voice recognition module, carefully selected for its accuracy in interpreting spoken commands, serves as the linchpin of this technology. The chosen module is meticulously aligned with the specifications outlined during the product planning phase, ensuring compatibility with the high-performance processors and memory of the central control unit. This strategic integration empowers users to navigate the wheelchair effortlessly through intuitive voice commands, fostering a seamless and responsive interaction between the user and the wheelchair's control system. The selected voice recognition system not only meets but surpasses the stringent requirements for precision and efficiency, elevating the overall user experience and reinforcing the wheelchair's position as an innovative and user-centric mobility solution.

Fig 4- Various Options Available In the Software Application To Drive The Prototype Of The Wheelchair. We Have Employed the Function Of Terminal As Well As Voice Control. The Application Can Also Be Controlled Through Arrow Keys

B. Solar Powered:

This commitment aligns with the growing awareness of the need for eco-friendly solutions, positioning the solar-powered wheelchair as a symbol of sustainability in mobility solutions. At the forefront of sustainable innovation, the voice-automated wheelchair incorporates an embedded solar power system, characterized by high-efficiency photovoltaic cells. Meticulously integrated into the wheelchair frame, these strategically positioned solar panels harness sunlight and adeptly convert it into a valuable source of electrical energy. To effectively manage the electrical output generated by the solar panels, the voice-automated wheelchair incorporates a solar charge controller into its system. This crucial component plays a pivotal role in regulating both voltage and current, ensuring a controlled and optimized charging process. The solar charge controller serves to prevent overcharging, safeguarding the battery and electrical components from potential damage. This sustainable energy solution not only aligns with environmental considerations but also contributes to the overall self-sufficiency of the wheelchair's power infrastructure.

C. Obstacle Detection:

Sensors, such as ultrasonic sensors, are fundamental for detecting obstacles in the wheelchair's path. This feature is paramount for preventing collisions and ensuring the safety of the wheelchair user. In essence, the choice of ultrasonic sensors in voice-automated wheelchairs is driven by their capacity for longer-range detection, adaptability to diverse conditions, and their crucial role in ensuring a proactive and reliable obstacle avoidance system for enhanced user safety. These sensors play a crucial role in detecting obstacles in the wheelchair's path, providing an additional layer of awareness and protection. By emitting ultrasonic waves and measuring the time it takes for them to bounce back after hitting an object, the wheelchair can ascertain the proximity of obstacles and make real-time adjustments to its trajectory. This capability is particularly beneficial for users who may have visual impairments or face challenges in promptly reacting to obstacles. By seamlessly incorporating ultrasonic sensors into the wheelchair's sensor systems, the technology not only enhances user safety but also underscores the commitment to creating a comprehensive and inclusive mobility solution that addresses the multifaceted needs of individuals with mobility impairments.

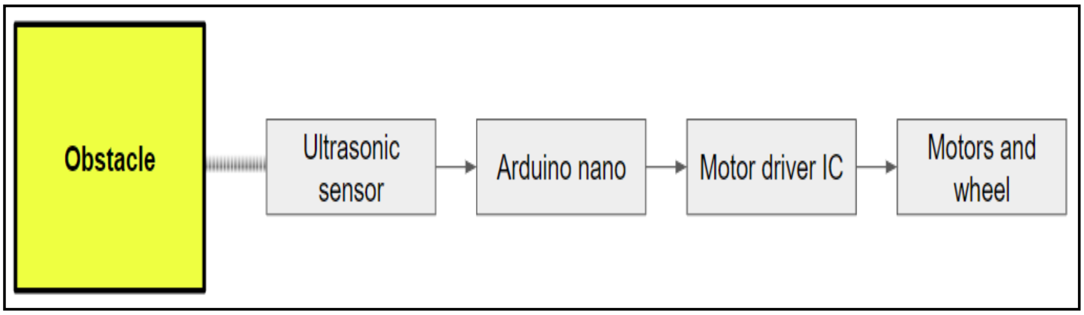

Fig 6- Block diagram of the working of Ultrasonic sensor and obstacle detection

D. Gesture Control System:

Apart from incorporating voice control, ultrasonic sensor for emergency navigation, Gesture control has also been incorporated replace the manual existing wheelchair with Powered wheelchair. To navigate the wheelchair using Gesture we have used gloves made up of synthetic cloth material, this glove is equipped with accelerometer gyro circuit also called MEMS (Micro electro mechanical system) The circuit helps in transferring our destination with gestures ie hand movements. The gloves consist of encoded IC and the wheelchair has decoder which decodes the signal coming from hand gloves then transfers the decoded signal to the microcontroller which operates the motor driver of the wheel chair. The Accelerometer measures the gesture static and dynamic forces then stores the measure of acceleration and move in coordinate axis.

The proposed prototype will be communicating wirelessly replacing the existing models where wheelchair is operated through remote or a joystick by the implementation of persons hand movements or gestures.

Working can be simply put in words like this- There is accelerometer gyroscope sensor also called MEMS placed on the glove which senses the hand movements or finger movements of the wheelchair user then encodes the signal in form of digits which are then send to the wheelchair via RF receiver and transmitter placed at wheelchair and gloves respectively. When the receiver receives the signal from the gloves it is decoded and further transferred to the Brain of the wheelchair which is IC which allows the motor drive to control the wheels attached to the body of wheelchair. RF module is working on a frequency of 433 MHz and has a range of 50-80 meters.

Additionally, the switching between the voice automation and gesture control through gloves has been done through a switch that in the “on” position works in favor of the Bluetooth module and in the “off” position works to operate the RF receiver in the wheelchair. The switch can be used to alternate the source of automation according to the favorability of the patient using the wheelchair.

5. System Control

The heart and brains of the powered wheelchair is in the controller as it provides both a conduit for the power to the motors and controls the overall system. [4] The objective of the project was to create a cutting-edge wheelchair that incorporates innovative technologies to enhance both sustainability and user safety. Central to this design is the integration of solar power for propulsion, a voice automation system utilizing the HC-05 Bluetooth module, and ultrasonic sensors to detect obstacles within a 20 cm range, automatically bringing the wheelchair to a stop and thereby preventing potential collisions.

The solar power aspect involves strategically placing solar panels on the wheelchair to harness sunlight. The photovoltaic cells within these panels convert solar energy into electrical power. This harvested solar energy is then employed to drive electric motors, providing a sustainable and eco-friendly source of propulsion for the wheelchair.

To achieve a holistic solution for all kinds of disabilities, a gesture control system is added which is controlled by the person in the wheelchair through hand movements (via gloves). The gloves are equipped with an accelerometer and gyro circuit, which includes an encoded IC (Integrated Circuit) and an accelerometer.

The accelerometer is crucial for measuring acceleration forces applied by hand movements in static or dynamic conditions. It records analog data for hand movements in X, Y, and Z directions. The prototype employs a wireless communication system, connecting gesture-controlled gloves with a wheelchair. MEMS sensors inside the gloves detect finger movements, serving as the interface between user gestures and the control system. The gloves wirelessly transmit signals to a receiver beneath the wheelchair, facilitated by a 433 MHz RF module with a 50-80 meter range. These signals drive the motor control system, comprising a motor driver and DC gear motor, converting the gestures into precise wheel movements. The integrated approach enables intuitive and responsive wheelchair control, enhancing user mobility and eliminating the constraints of traditional wired systems.

The below figure illustrated the proper working of the prototype wheelchair and the connections between the subsystems and the systems.

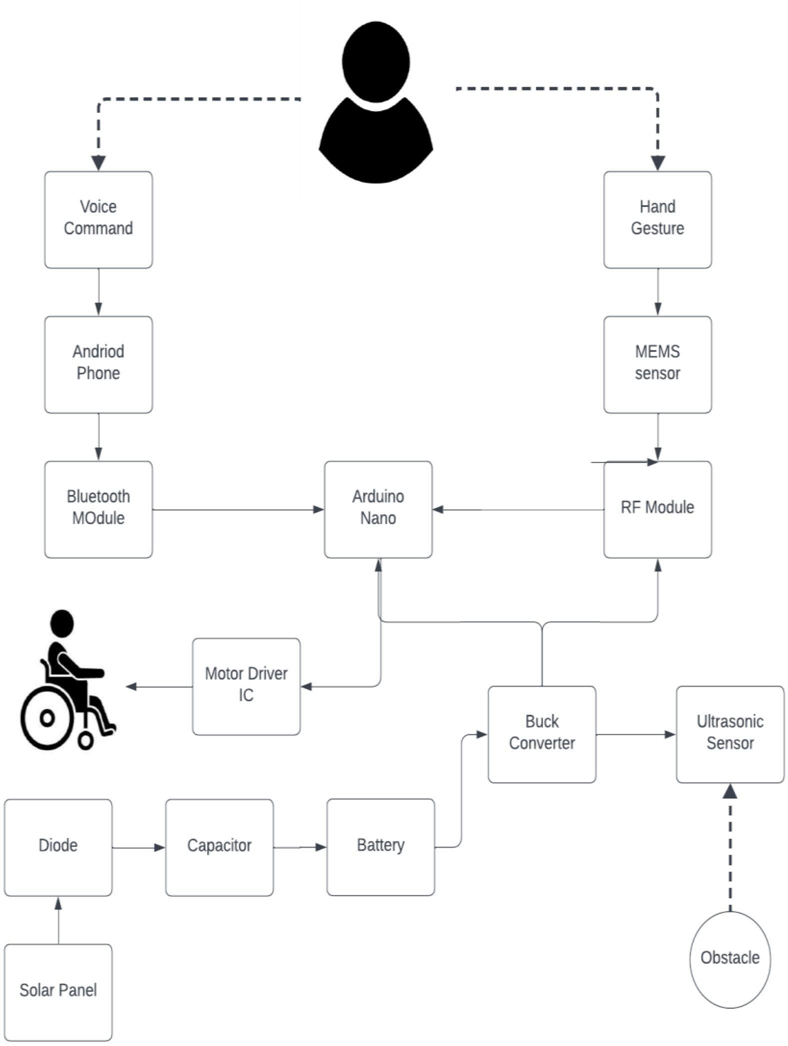

Fig 7-The block diagram of the model wheelchair

6. Conclusion

The voice-automated solar-powered wheelchair equipped with ultrasonic sensors manifests a revolutionary advancement in the medical field to elevate comfort for the disabled. The model provides a commercially viable solution combining ultrasonic sensors and speech recognition. It stands out in terms of users with limited movability as it incorporates gesture control features. It excels the manual wheelchairs as it has solar-powered batteries helping us to gain sustainability. The integration of AI, GPS, and alternative sources for eco-friendly charging will be part of future advancements. Though it has potential cost implications, it holds an optimistic future of improving patient care and their subjective well-being, highlighting how vital a role it will play in the future of medical technology.

7. Results

We developed a sophisticated wheelchair design (CAD model + real-time model) that can be:

1. controlled via voice commands
2. will be equipped with emergency directional changing and stopping mechanisms.
3. will have provision to solar charge the battery (using a non-conventional energy source)
4. can be controlled using gestures via Hand Gloves connected wirelessly

We also focused and achieved on optimizing the design elements of the wheelchair including the placement of the motor, patient, and battery arrangement in the CAD model for the optimized usage of energy and Integrated solar charging technology with the voice-automated wheelchair to achieve an alternate source of energy charging We also implemented strategic sensor placements to enhance the effectiveness of the stopping mechanism, ensuring a precise and reliable response, and also designed a gesture-controlled wheelchair capable of performing above tasks seamlessly via a hand glove connected to wheelchair wirelessly for the required customer.

The combination of Voice automation, gesture control and Ultrasonic emergency stop System provides an ultimate product that can be used by different types of people owing to their various types of disabilities. The voice and gesture-controlled wheelchair can easily welcome the dumb through gesture control, and the deaf through voice automation and can assist the blind with an emergency stopping mechanism with the help of ultrasonic sensors.

If a person is physically handicapped and can't use his hands then voice automation can be used instead of gesture control. Thus the proposed wheelchair works as a combination of different ways to become a ‘powerchair’ unlike the traditional self propelled wheelchairs.

The switching between the voice automation and gesture control through gloves has been done through a switch that in the “ON " position works in favor of the Bluetooth module and in the “off” position works to operate RF receivers in the wheelchair. The switch can be used to alternate the source of automation according to the favorability of the patient using the wheelchair.

8. Future Scope

The voice-automated solar-powered wheelchairs hold a promising future to cater to the needs of the elderly through some innovative features like the integration of speed control and enhancing other mechanisms of lifting and gearing. The incorporation of brain signals with the help of AI for the optimized movement in various paths can be a mold-breaking innovation. In addition to solar energy, eco-friendly charging can be achieved by harnessing wind and noise energy. Also, the inclusion of real-time tracking and route optimization can be done through GPS for convenient navigation. The future focus would be mainly on improving speech recognition and optimizing solar energy and sensors. A cloud-based connection and adaptive interference will guarantee a seamless user experience. These accessible mobility solutions will demand the synergy of researchers and healthcare professionals.

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