

Smart Wheelchair with Voice Control and Device Following Capability

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Abstract:- One billion people, or 15% of the world's population, experience some form of disability, and disability prevalence is higher in developing countries. Such disabilities stem from accidents, diseases, etc., and the people it affects need good and accessible solutions. Physical disabilities, which impact a person's ability to move, often come with other disabilities, and this makes the use of assistive equipment such as wheelchairs inadequate. People with additional impairments of hands and arms find it difficult to use a traditional wheelchair. One of the existing solutions for this, is the utilization of wheelchairs that can be controlled through voice commands. Despite that, there remains a subset of people who are unable to navigate their wheelchair on their own and rely on the assistance of a caretaker. To overcome the mentioned challenge, the objective of this work is to design and develop a Smart Wheelchair with Voice Control and Device Following Capability. The wheelchair is operated using voice commands given by the user. Another mode of operation included in the smart wheelchair is to follow a caretaker which eliminates the need for the caretaker to manually push the wheelchair. The automatic obstacle detection system is integrated into the developed wheelchair by using ultrasonic sensors in order to stop the wheelchair whenever any obstacles come in the way, to ensure smooth and safe movement.

Keywords: Bluetooth module, Human Tracking, Smart wheelchair, Voice recognition module.

1. Introduction

According to a survey made by the World Health Organization, more than 1 billion people in the world have some form of disability. This accounts for about 15% of the world's population. As per India's latest statistics, an estimated 2.1 percent of the Indian population has a disability; a humbling figure of over 2.6 million people [1]. A person can face disability, either intellectually or physically, at any point in their life from medical complications or life-altering events. Specialist medical attention is required throughout a patient's life, along with access to affordable medication and assistive technologies to improve the quality of living. A traditional wheelchair is one of the most widely used mobility products. But in many situations traditional wheelchairs are not adequate. To tackle this problem motorized wheelchairs were introduced where the user could control using a joystick [2] or keypad mounted on the armrest, using hand gestures [3], [4],[5], tongue control [7] and brain control base methods [8] are also available. These wheelchairs, although more expensive than its traditional counterpart, greatly reduced the effort required to use them. But for users with limitations such as poor hand-eye coordination, motor skills, and disability affecting their hands, it was difficult to control such wheelchairs with existing control mechanisms. Voice is also considered the most natural way of communication [8].

Hospitals, Clinics, Airports, Railway stations, Elderly care homes etc. are various places that require the use of wheelchairs for their patients/users, and quite often the personnel/staff have their hands occupied which deters them from manually pushing the wheelchair.

Taking into consideration both factors, we have built a prototype that caters to disabled people by providing them a wheelchair that can be operated in two modes. If the person chooses to commute independently through the wheelchair by themselves, they can use voice commands as the mode of operation. However, if they need a caretaker by their side, the second mode of operation comes into action where they are provided with the ability to follow a person using Bluetooth based position estimation, eliminating the need for the caretaker to manually push the wheelchair. The system aims to make the operation of the wheelchair hands-free and reduce muscular strain on the personnel.

Therefore, in the proposed prototype, the wheelchair is operated using voice commands from the user. These commands will be received by the microphone of a voice recognition module. The voice commands issued by the user are then matched with the trained commands stored in the voice module. This allows the user to operate the wheelchair without assistance from anyone. In cases where the assistance of a caretaker is advised, the proposed system also provides the capability to follow a person by a human tracking system. This is done using Bluetooth based position estimation by utilizing RSSI and IMU values. The program checks the status of the ultrasonic sensors to check for any obstacles in the path. If there are no obstacles found in the current direction of the wheelchair, the motors are activated [9],[10].

2. Related Work

Over the years, many researchers have come up with different solutions on controlling a wheelchair through voice commands.

In one such solution, a Raspberry Pi microcontroller board was utilized as the central processing unit to receive and interpret voice commands from the user. Various speech recognition algorithms and techniques were employed to accurately recognize and convert the user's spoken commands into wheelchair movements [11],[12]. A similar approach was employed by another research. Sensor technologies such as proximity sensors, infrared sensors, or camera-based sensors were incorporated autonomously to detect obstacles and enable wheelchair navigation. Hands-free control of the wheelchair has also been pursued by researchers. The laser range sensor was employed as the primary technology for detecting and tracking a guide person or object. Various control algorithms, including proportional-integral-derivative (PID) control, were considered to process the sensor data and make necessary adjustments to the wheelchair's movements. This method utilized the accuracy and reliability of laser range sensors to enable precise navigation and seamless guide following, thereby enhancing the overall functionality and usability of smart wheelchairs in dynamic environments. However, this approach is not cost-effective and is unsuitable in scenarios with multiple individuals moving within the environment [13].

Another approach for achieving device-following capability involves Bluetooth-based position estimation. In this technology, experimentation has been conducted to develop a robot capable of tracking a user using Bluetooth-based position estimation. The study utilized Bluetooth technology to establish a wireless communication link between the user's device and the robot. Through the utilization of Bluetooth signals and triangulation techniques, the robot can estimate the user's position and make necessary adjustments to its movements. This technology facilitates accurate tracking and navigation, thereby enhancing the robot's effectiveness in following the user [14].

This approach of using Bluetooth-based position estimation by a smartphone seems to be economical. Hence, a similar approach was incorporated to achieve a device following capability in our wheelchair system.

As part of research, it was found that there is no Smart Wheelchair available with combined features of following a caretaker and using voice commands as the mode of operations. Despite there being good contributions on using voice as a mode of operation, it is more beneficial if there is an additional feature where the wheelchair can follow the caretaker. The approach of using Bluetooth based position estimation [14] for following the caretaker is the first of its kind in the smart wheelchair domain.

3. Methodology

3.1 Voice Module

The microphone connected to the voice module is used to receive commands from the user and convert them into electrical signals. The user's voice commands must be trained and these commands are converted to electrical signals, digitized and stored in the voice module as templates. When the user provides the command to the system, if the user command matches to the stored command, the voice module gives the output to the microcontroller. In addition, the microcontroller receives signals from the front and rear ultrasonics, which help in obstacle detection. The microcontroller output is attached to the DC motors which gives the movement to the wheelchair. Depending on the voice signal provided, the corresponding motors are powered to provide the necessary movement.

The working of the voice module system in the wheelchair can be presented as a flowchart shown in Fig. 1. There are five types of motions in this wheelchair - moving forward, backward, moving to the left, right and halt. The system receives the input voice command from the user and implements one of the 5 possible types of motion accordingly. For the forward command, the wheelchair moves in the forward direction as the right and left motors turn forward. For the backward command, the wheelchair moves in the rear direction as the right and left motors turn backward. The Left command will result in turning the right motor forward. The Right command will result in the left motor turning forward. For the Stop command, the rotation of both motors will be stopped. The ultrasonic sensors installed at the front and rear of the wheelchair keep checking for obstacles and will stop the movement of both motors immediately when any obstacles are detected. The wheelchair system will go back to standby mode. This process goes on until the power supply is cut off.

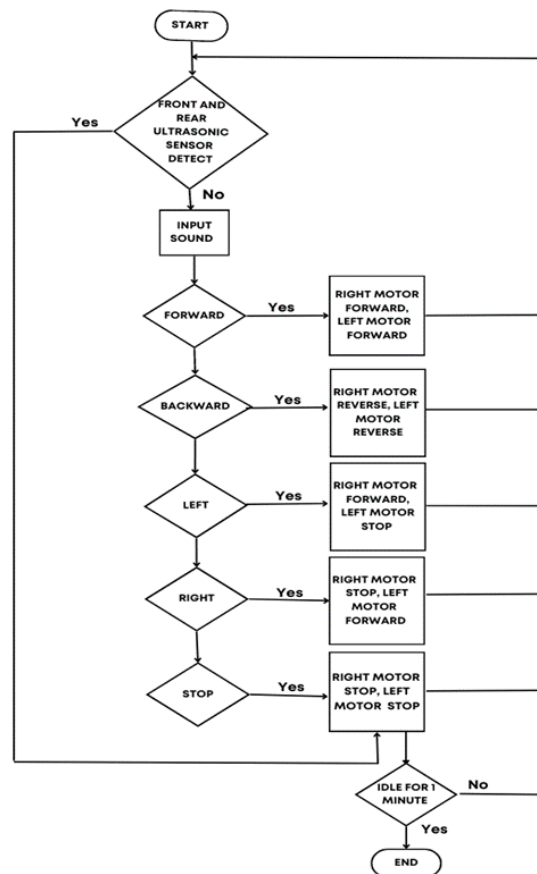


Fig. 1. Flow of the voice module system

3.2 Follow the Care taker

The proposed system is also devised to utilize the IMU and Bluetooth RSSI readings obtained from a smartphone, to estimate the position and direction of the caretaker. To obtain the relative estimate of the target's position (during the motion). RSSI values need to be converted into distance. A regression model called Linear Approximation model is used. Although there are many estimation models, a regression model is comparatively less computational [15].

Equation (1) represents a Linear approximation model, where d is the distance between the smartphone and the raspberry pi. To obtain the a and b values a curve fitting approach is used (Least Square Approach).

$$RSSI = -a * \log(d) + b \quad (1)$$

The working of the following a caretake module is shown in Fig. 2. The motion estimation module is used to send motion commands to operate the wheelchair and it begins with establishing a Bluetooth connection between the

smartphone and the raspberry pi. On receiving the RSSI and IMU values it estimates the direction and distance of the target with respect to the wheelchair and then sends the motion commands based on the target's position. When Raspberry Pi receives the RSSI and IMU magnetometer values, it converts RSSI into estimated distance using a Linear Approximation Mode.

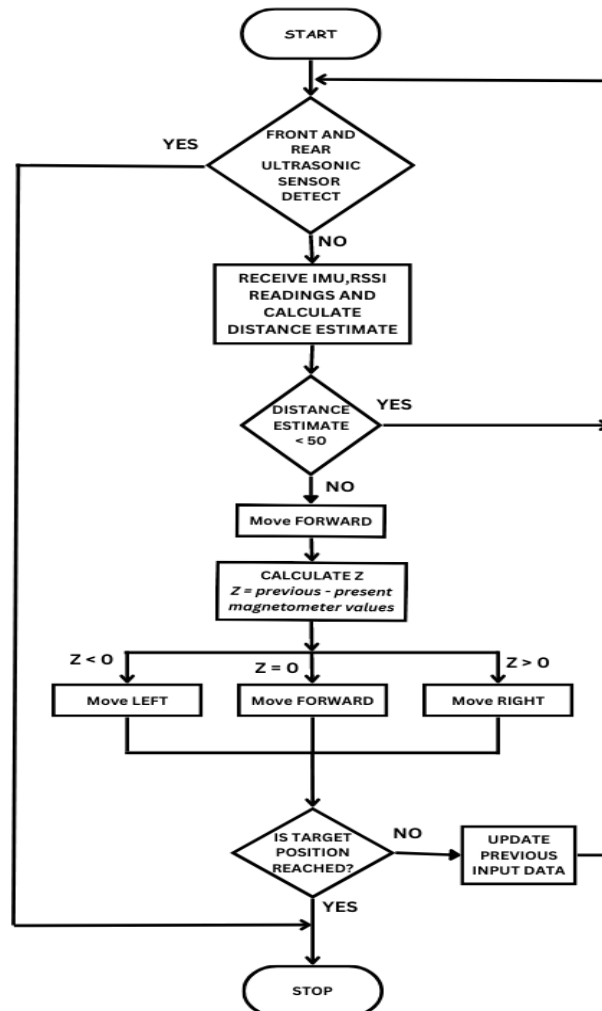


Fig. 2. Flow of the following caretaker module

If the estimated distance is less than 50cm, the wheelchair halts as it implies to be close to the caretaker. Else, the wheelchair moves forward and the pace of the wheelchair is determined by calculating the difference between the current and previous estimated distance. If this difference is greater than the previous difference, then accelerate the wheelchair and if the difference is less than the previous difference, it is slowed down.

Then, the difference between the present and previous IMU readings are calculated. If the difference is less than 0, which is the considered threshold, then the wheelchair moves forward. If the difference is Positive, then the wheelchair turns left, by powering the right motor. If the difference is Negative, then the wheelchair turns right, by powering the left motor.

Then, the previous data is updated with the current values and the raspberry pi goes on to capture the latest RSSI and IMU readings.

The ultrasonic sensors installed at the front and rear of the wheelchair help in obstacle detection. If an obstacle is detected, the motors are halted and the system goes to a standby mode. This process continues until the user's decided destination is reached.

4. System Implementations

The proposed system shown in Fig. 3 provides the user with 2 modes of operation of the wheelchair. First mode is to control the wheelchair based on voice commands given by the user. Second mode operates by following the caretaker. The choice of selecting the desired mode is based on a switch mechanism.

If the selected mode is Voice controlled module, then the user input is taken via the microphone of a voice module. This paper uses the V3 voice recognition module for reading the commands. The user's voice commands must be trained, and these commands are converted to electrical signals, digitized and stored in the voice module as templates. When the user provides the command to the system, if the user command matches to the stored command, the voice module gives the output to the raspberry pi microcontroller.

If the selected mode is to follow a caretaker, then a Bluetooth connection is established between the raspberry pi which is placed on the wheelchair and the smartphone which is held by the caretaker. The RSSI readings are extracted using the pybluez library. IMU readings are obtained from a Transmission Control Protocol (TCP) client App like Phyphox and it's transferred to the raspberry pi. On receiving the RSSI values and IMU values, are used to determine the direction of movement of the wheelchair. Once the microcontroller has received the commands, the L298N Motor Driver powers the respective motors.

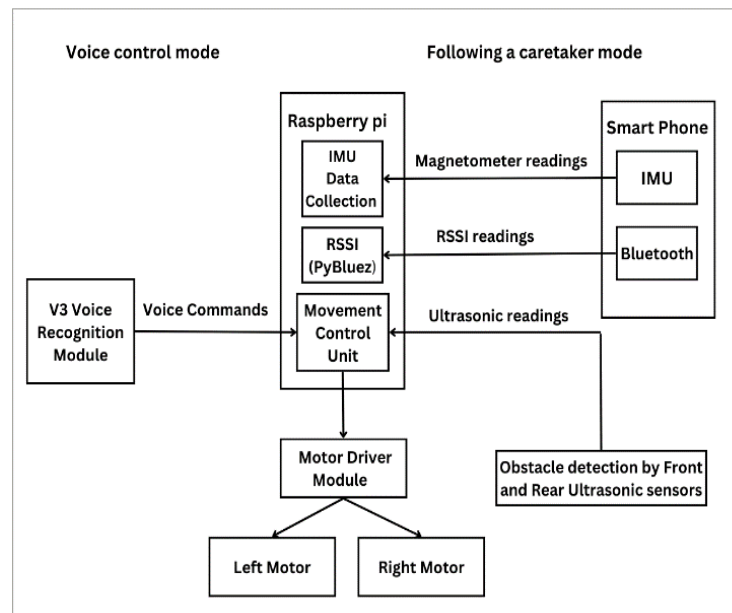


Fig. 3. Block Diagram of the system

The wheelchair avoids obstacles using the two ultrasonic sensors placed at the front and rear. When an obstacle is detected by either of these sensors, the wheelchair is halted.

5. Result and Discussions

In this project, the average response time of voice commands was measured to assess the system's efficiency and responsiveness. After conducting multiple tests, the results for the average response time are shown in Fig. 4.

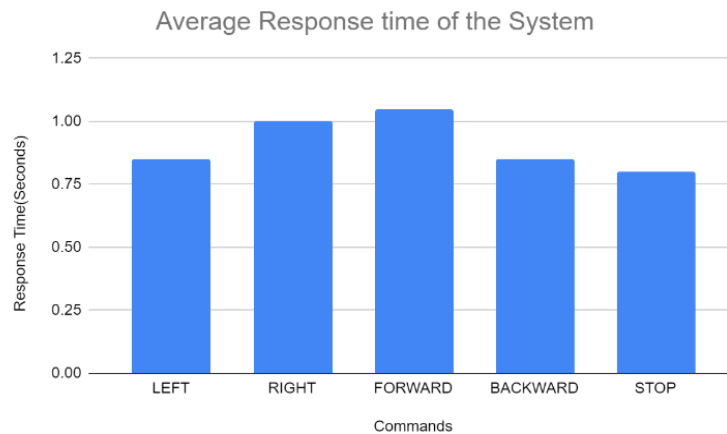


Fig. 4. Average response time of the system to voice commands.

These results demonstrate the V3 voice module's capability to interpret voice commands and swiftly respond to the user's instructions. The system's average response time ensures a smooth and seamless navigation experience for the user, enhancing the overall usability and functionality of the voice-controlled wheelchair project.

The accuracy of the system in correctly identifying and understanding voice commands was evaluated. Here are the results for the number of correct identifications of the command.

Table I: Accuracy estimate of the voice module.

Sl.NO.	Commands	Number of correct identifications out of 10	Accuracy Percentage (%)
1	Left	9	90
2	Right	8	80
3	Forward	7	70
4	Back	9	90
5	Stop	10	100

The results in Table I indicate that the V3 voice module exhibited varying levels of accuracy in identifying the voice commands during testing. While the system achieved perfect accuracy for the "Stop" command, it encountered some challenges in recognizing certain instructions consistently. The "Forward" and "Right" commands, in particular, showed relatively lower correct identification rates, with the system misinterpreting some inputs.

It is essential to note that while the V3 voice module demonstrates promising potential, there is room for improvement in enhancing its voice recognition capabilities, especially for certain commands. Further refinements and optimizations may be required to ensure more consistent and reliable performance in real-world scenarios.

Despite the occasional misidentifications, the V3 voice module still represents a step forward in assistive technology, offering users an alternative means of controlling the wheelchair. Continued testing and iterative improvements are necessary to achieve higher accuracy and enhance the overall usability of the voice-controlled wheelchair project.

The prototype was tested in a dedicated path which would be the case for wheelchairs in airports and railway stations where there is an assigned path for disabled people. Table II depicts the results of the distance estimate from RSSI using log-path model and it is compared against the actual distance which helps us in assessing the system's performance accurately and interpreting the user's actions based on the RSSI values, which are usually negative. The Mean RSSI value is considered to calculate the predicted distance.

Table II: Distance estimate from RSSI using log-path model

Sl. No.	Actual Distance (in cm)	Mean RSSI Value	Predicted Distance Log-Path (in cm)
1	21	-41	6.02
2	80	-60.2	89.62
3	90	-63.3	139.58
4	120	-61.5	107.59
5	175	-65	176
6	250	-66.2	208.35
7	370	-71.8	457.86
8	400	-69.9	350.52
9	450	-69.6	336.05
10	500	-70.2	365.2

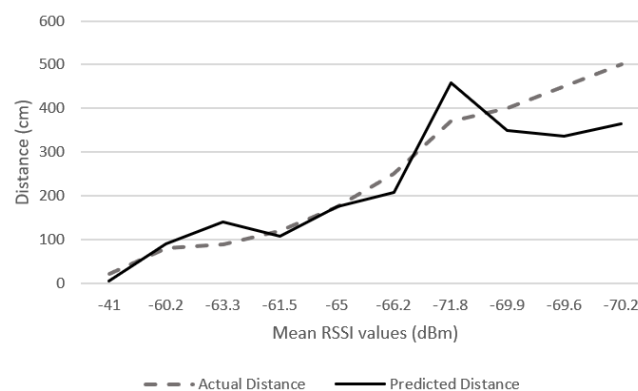
**Fig. 5. Plot of actual distance vs predicted distance.**

Fig.5 shows the plot of actual distance vs predicted distance that helps in understanding the system's accuracy and identifying areas for improvement to ensure a more seamless and reliable "Follow the Caretaker using RSSI" experience.

6. Conclusion

In conclusion, the integration of voice module and caretaker-following capabilities in a wheelchair represents a significant advancement in assistive technology for individuals with mobility impairments. This innovative prototype harnesses the power of voice commands to provide an intuitive and hands-free control interface. Furthermore, the incorporation of caretaker-following functionality enhances safety and convenience of the caretaker, as it ensures seamless navigation in dynamic environments.

In the future, hardware enhancements can be done to convert the prototype to a fully functional wheelchair. Improved tracking algorithms, and advancements in AI and sensor technologies enhances the precision, adaptability of the wheelchair and reduces the error between predicted and actual distance. These innovations have the potential to greatly enhance the quality of life for individuals with mobility limitations, enabling increased freedom and confidence in navigating in the crowded areas.

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