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Research article

A wireless controlled intelligent healthcare system for diplegia patients

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Abstract: Rehabilitation engineering is playing a more vital role in the field of healthcare for humanity. It is providing many assistive devices to diplegia patients (The patients whose conditions are weak in terms of muscle mobility on both sides of the body and their paralyzing effects are high either in the arms or in the legs). Therefore, in order to rehabilitate such types of patients, an intelligent healthcare system is proposed in this research. The electric sticks and chairs are also a type of this system which was used previously to facilitate the diplegia patients. It is worth noting that a voice recognition system along with wireless control feature has been integrated intelligently in the proposed healthcare system in order to replace the common and conventional assistive tools for diplegia patients. These features will make the proposed system more user friendly, convenient and comfortable. The voice recognition system has been used for movements of system in any desired direction along with the ultrasonic sensor and light detecting technology. These sensors detect the obstacles and low light environment intelligently during the movement of the wheelchair and then take the necessary actions accordingly.

Keywords: intelligent wheelchair; diplegia patients; wireless controlled wheelchair; intelligent healthcare; RF transmitter and receiver; ultrasonic sensor

1. Introduction

The role of rehabilitation engineering has been evolved in recent years, as assistive and universal design technology it allows the disable people to participate, interact and thrive normally in this world. The first smart wheelchair which was electric-powered technology was developed by a scientist of NRC (National Research Center) Canada. These wheelchairs were used to help the injured people after the World War II [1]. The electric wheelchairs have become more efficient, quieter and lower maintenance in general for the users. It provides people more freedom with less assistance in terms of control, styles, range or travel distance, maneuverability, seating and other user options [2]. In contrast, the mobility of the manual wheelchair was limited by the user's physical condition and restricted his or her daily activities. Furthermore, a joystick control was inefficient for the person who has no arms or persons who lost their upper extremities due to injury in an accident [3]. Some of the patients who have quadriplegia, multiple sclerosis and cerebral palsy deceases are not able to move around and thus lose their freedom of movement [4–7]. In order to provide the best solution for such type of people and to get the maximum benefits of the powered wheelchair, a voice recognition system was employed for controlling the movements of wheelchair [8–10]. Although recent scientific and technological developments have completely changed the lifestyle and way of living for a normal person, but there are certain groups of people who are not able to get benefits from this evolution. Disabled people with mobility problems still live a life with limited mobility. The researchers are trying to develop other electric wheelchair control technologies, whose goal is to improve the living lifestyle of disabled people. These experiments include a voice controlled [11], a brain controlled [12], an eye controlled [13,14] and natural voice communications [15] for the wheelchair. Generally, there are a variety of motorized wheelchairs available in the market designed for special persons with various features. For example, a wheelchair that can run with an analog joystick, touchpad switch, controlled with head movements, eyeball, prescribed paths on given routes, and so on [16,17]. However, still, voice recognition is regarded as one of the most promising technology due to increasing signal processing capabilities [18–21]. The disadvantage of a voice-controlled wheelchair developed previously is its low immunity to noisy environments, which may distract the system's attention and lead to its incorrect response. In the brain control wheelchair-using EEG signal, patients can easily control it, but the setting method is impractical.

An intelligent smart wheelchair is a kind of mechanical control equipment, which is specially designed to use the user's control of self-action. This reduces the manpower and power for the user to turn the wheel of the wheelchair and it is a great development in an Intelligent Healthcare System. In addition, it provides an opportunity for people with visual or physical disabilities to move from one place to another. Smart wheelchairs have attracted a lot of interest recently. These devices are particularly useful when moving from one place to another. These machines can also be used for old people who have no disabilities but they feel difficult while moving in home. These devices are a blessing for those who have lost their mobility. In the past, different types of intelligent wheelchairs have been developed, but the new generation of wheelchairs developed by the use of artificial intelligence in its design, thus leaving some space for the DIY of wheelchair users.

Previously, an electrical wheelchair doesn't have the sufficient features for those patients who are suffering from paralysis and who spend most of the time on beds. In this research, the human voice is recognized to control the commands used for movements of the wheelchair because voice provides an easy interface and is a way of natural communication. The proposed wheelchair is also equipped with an obstacle detection system, which reduces the possibility of collision when driving. The design of control system for intelligent wheelchair is also presented in this research which leads to novelty of the system. The circuitry of hardware and programming are debugged and verified, for the same person the recognition rates are acceptable of voice operated wheelchair. As a result, it works flawlessly with proper inputs even in a noisy environment. Also, in this paper the basic nine functions i.e., forward, backward, right, left, rotation, stop and three (low, medium and high) speed-controlled modes have been employed in a voice-recognition system along with wireless control to facilitate the disabled person to a greater extent. Moreover, obstacle avoidance from the backside of the wheelchair where a patient can't see has also been provided by installing obstacle sensors at the backside.

2. Materials and methods

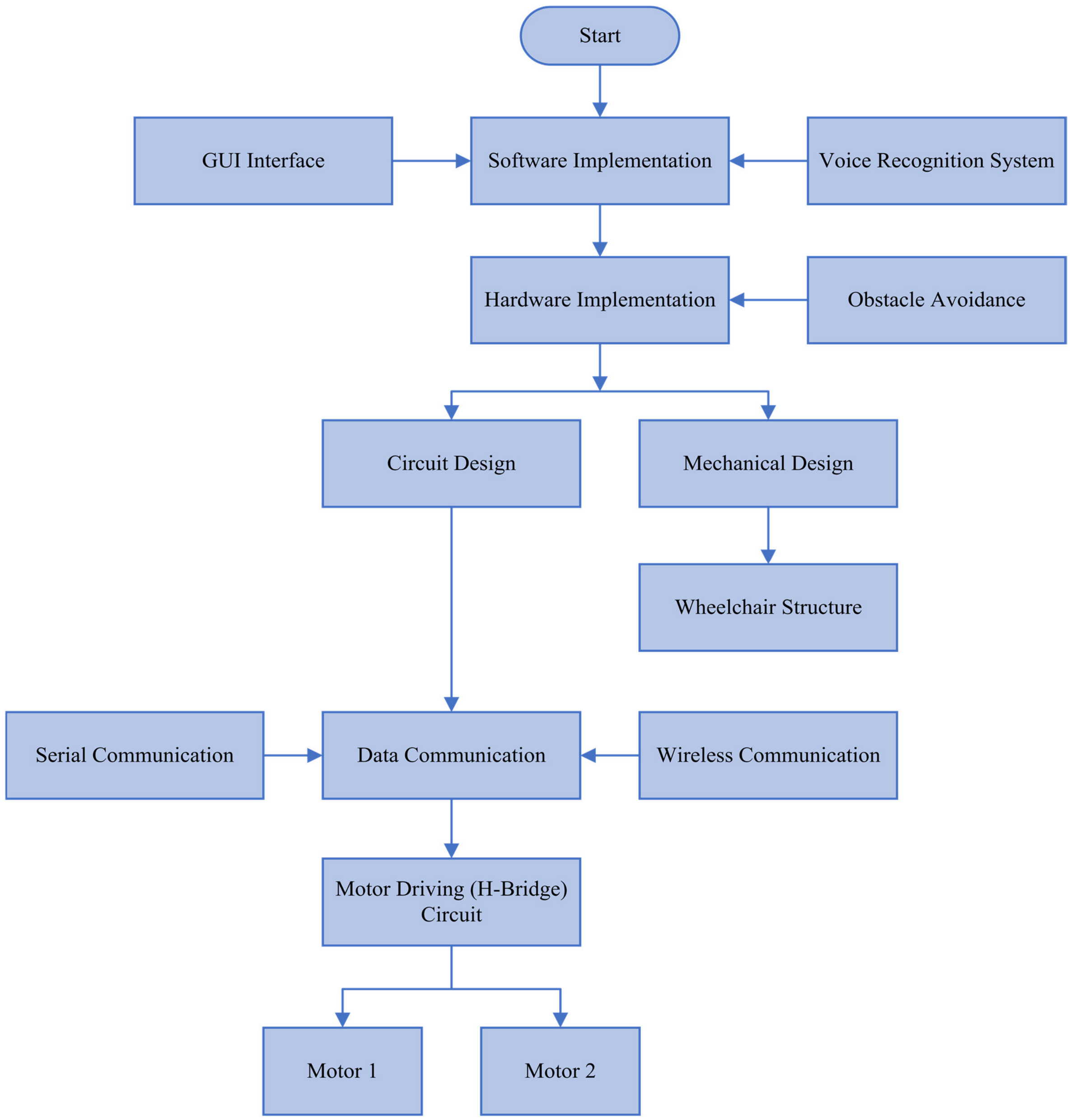

Figure 1. The flow chart of overall approach and methods for the proposed research.

The purpose of smart wheelchairs is to provide some mobility and assistance, which will greatly help the persons who are physically disabled. A smart wheelchair consists of a major controller unit that allows the user to provide the input in the form of a joystick or accelerometer or a voice command. The controller unit then synthesizes the command and takes the required action to move the wheelchair to a position. The overall approach of this work is given in Figure 1. This flow diagram explains how the movements of a wheelchair can be controlled with wired and wireless communication. The Motor 1 and Motor 2 in the block diagram are connected parallel with each other. If the controller command to Motor Driving Circuit is “forward” then both the motors starts moving forward. In order to obtain the objectives of this research work, software and hardware implementation have been done simultaneously.

In the software part, a built-in library of visual studio is used for voice recognition of the user. A Graphical User Interface (GUI) is designed in Visual Studio to provide visual interaction to the user for basic functions of the wheelchair as shown in Figure 2. The GUI interface is designed in MATLAB for wireless data communication between laptop and wheelchair. Recently, this interface is working in Laptop but in future recommendation an android App will be developed to facilitate the mute persons. Circuit designing for driving the motors with wire and wireless communication is the main work in the hardware implementation. Wireless communication has the plus advantage to provides an extra feature that facilitates some other person (sitting on the remote side) to control the movements of the patient’s wheelchair. Especially, this wireless control of the chair helps the type of patients who are mute or cannot speak. Such people who cannot speak, they have this additional feature to control the wheelchair. The voice sensors are not trained to specific person in fact they can recognize any similar voice which is debugged in the controller. Like if someone calls, “forward” then the wheelchair starts moving to the forward direction.

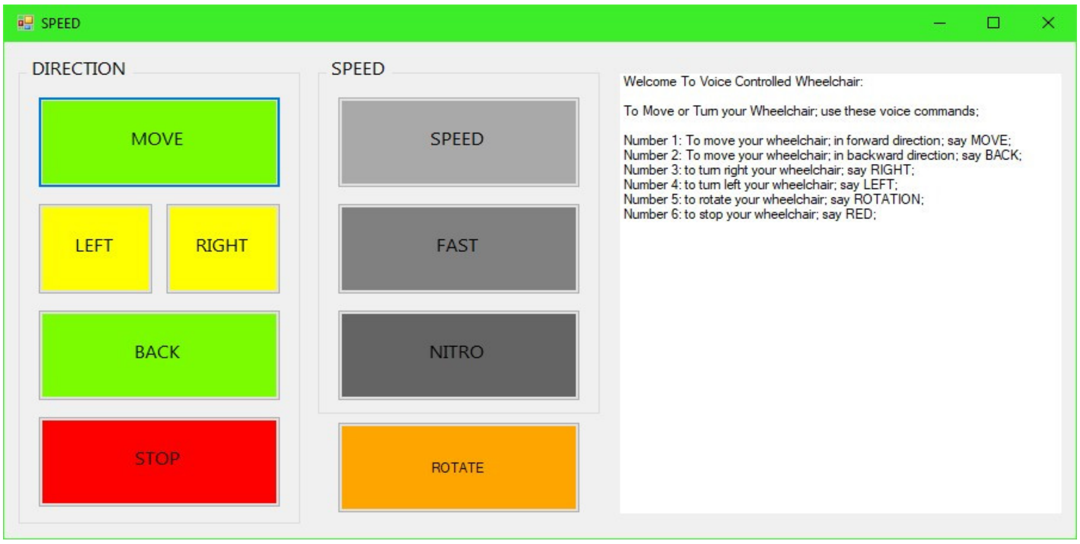

Figure 2. The GUI commands interface designed in MATLAB to control the input parameters.

It is worth mentioning that the mechanical design of a wheelchair is of crucial importance in order to control the wheelchair movements. Mechanical movements are based on the motor drives and motors installed for the chair movements. The motor driving flow chart is given in Figure 3. It shows that serial communication is used either to control or to receive data from an embedded microprocessor. MAX232 IC is used as a dual transmitter and dual receiver that converts RX, TX, CTS and RTS signals. This IC is used in the communication system (RS232) that converts the voltage levels on TTL devices which are interfaced with the PC serial port and microcontroller 89c51.

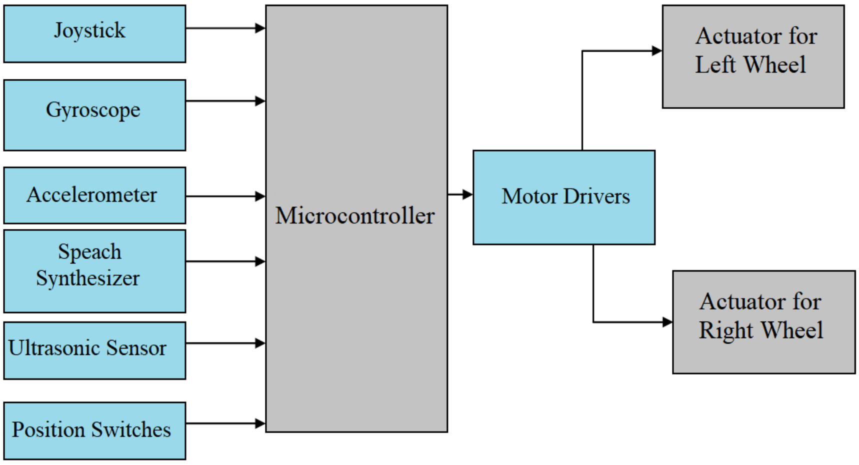

Figure 3. The basic structure for driving the wheelchair motors in any direction using controller.

This mechanical control takes actions as per the instructions received from the controller which is in sending control commands as per the voice signals. In this mechanical circuit, data is transmitted serially through the virtual terminal. Motors are controlled well with a H-bridge circuit according to the mentioned voice commands. For virtually data transmission, the virtual serial port driver has been used as shown in Figure 4.

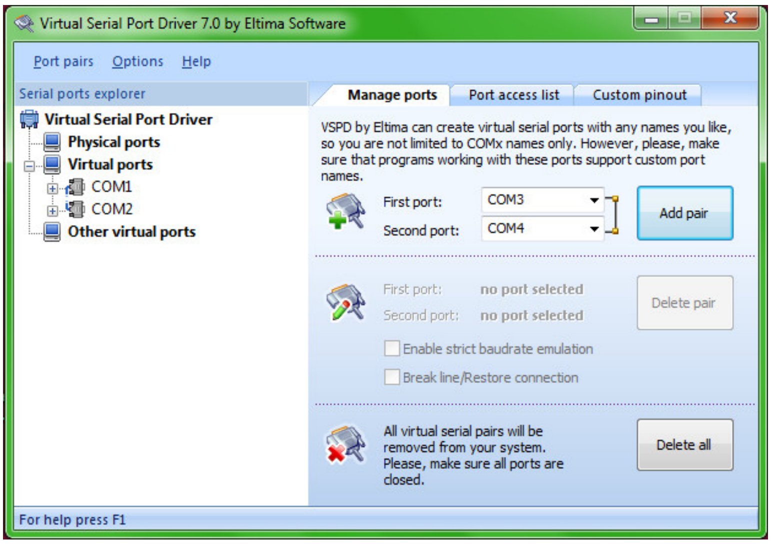

Figure 4. The virtual serial port driver designed for the wireless control of wheelchair.

2.1. Calculation of mean squared error

When we take the average of the squares of all the errors then it is called mean squared error (MSE) and it is calculated to minimize the effect of troubleshoot errors in the intelligent systems. The mathematical expression for the calculation of MSE is as represented in Eq (1).

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \tag{1}$$

In order to find the MFCCs (Mel Frequency Cepstral Coefficient), the troubleshoot errors are segmented into frames and windowing is done by using Hamming window. The mathematical representation of hamming window is shown below.

$$S_P = \sum_{n=0}^{N-1} S_n e^{-j2\pi pn/N}, P = 0,1,2,3,...,N \tag{2}$$

The Mel-scale is also known as a non-linear frequency scale, the mathematical relationship between normal frequency and MeI-scale is expressed in Eq (3). The non-linear mapping is a dimension reducing method which attempts to retain the distances between data points as well as possible. So, this technique is integrated with the proposed intelligent system to retain the troubleshoot errors for obstacle detection.

$$M(f) = 1025\ln(1 + f/900) \tag{3}$$

$$C_n = \sum_{l=1}^{K} (\log S_l)\cos[n(l-\frac{1}{2})\frac{\pi}{K}], n = 0,1,...,K-1 \tag{4}$$

The log value of Mel-frequency spectrum can be found by using the above expression. The discrete cosine transform was done for logarithmic Mel-frequency spectrum. By finding the Inverse FFT of the resultant signal, we get the MFCCs of the corresponding input signal. The mathematical equation for Discrete Cosine Transform (DCT) can be written as in Eq (4).

3. Results & discussions

The proposed technique is physically implemented, and simulation results with other features are verified in this research by using the following steps.

3.1. Wireless serial data communication

Wireless serial data communication has been employed in order to add extra features to this wheelchair. This provides a capacity in which some other person (sitting on the remote side) can control the movements of the patient's wheelchair if required There are two constraints for wireless system designing (i) it must be operated from a certain distance and (ii) it transfers a certain amount of information [23]. For serial data communication board wireless, RF (Radio Frequency) transmitter and receiver are used in this research work because according to size, its dimension is very small. Operating voltage range and corresponding frequency range varies 3 V to 12 V and 3 kHz to 300 GHz respectively. As compared to many reasons, its transmission has best qualities than Infrared i.e..

1) The signal can travel through long-distance when the obstacle is present between transmitter and receiver.
2) It uses specific frequency for communication purposes while IR signals affected by other emitting sources [24,30].

The serial data is received by RF transmitter and it transmits the data wirelessly through an antenna connected with it. In the RF module, the transmission rate occurs 1 Kbps to 10 Kbps having the same frequency of both (transmitter and receiver). The block diagram as shown in Figure 5 clearly explains how wireless data will be transmitted. Since RF transmitter needs 12 V for the proper function which may damage the microcontroller circuit so the use of optocoupler in between RF transmitter and microcontroller circuit is necessary to provide protection to the microcontroller circuit.

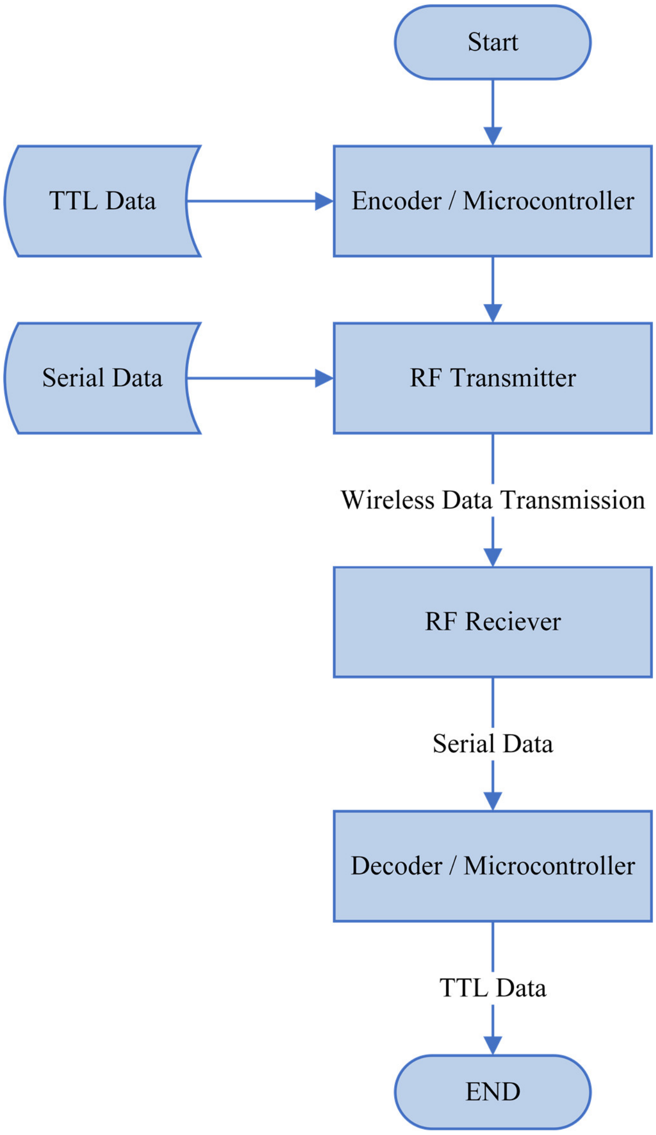

Figure 5. The flowchart for the working principle of wireless data transmission in the system.

When a character is sent against a voice command, the PT 2262 IC in the RF transmitter encodes the four-bit data into one bit and transmit into the air. At the receiver side, PT 2272 IC decodes this one-bit data into four bits which then sent to the microcontroller to control the motors according to required operations. For display purposes of the running operation, a seven-segment display also interfaced with the system. This wheelchair utilizes nine combinations of data out of sixteen for getting the required operations as given in Table 1.

Table 1. The bits-combinations used for the transmission of data according to given commands by using GUI interface.

Operations for VCW	ASCII Character for Operations	Selected Combinations of bits
Forward	F	0 x 01
Speed mode 1	1	0 x 02
Speed mode 2	2	0 x 03
Speed mode 3	3	0 x 04
Stop	S	0 x 00, 0 x 05, 0 x 0A, 0 x 0B, 0 x 0C, 0 x 0D, 0 x 0E, 0 x 0F
Backward	B	0 x 06
Left	L	0 x 07
Right	R	0 x 08
Rotate	O	0 x 09

When a character is sent against a voice command, the PT 2262 IC in the RF transmitter encodes the four-bit data into one bit and transmit into the air. At the receiver side, PT 2272 IC decodes this one-bit data into four bits which then sent to the microcontroller to control the motors according to required operations. For display purposes of the running operation, a seven-segment display also interfaced with the system. This wheelchair utilizes nine combinations of data out of sixteen for getting the required operations as given in Table 1.

3.2. Direction control topology

An H-bridge is a simple circuit that lets you control a DC motor to go backward or forward. You normally use it with a microcontroller, such as Atmel, PIC or Arduino, to control the motors [31]. Figure 6 representing the proposed H-bridge to control the motors for the wheelchair. When it can control two motors to go either forward or backward then it's easy to build a simple robot.

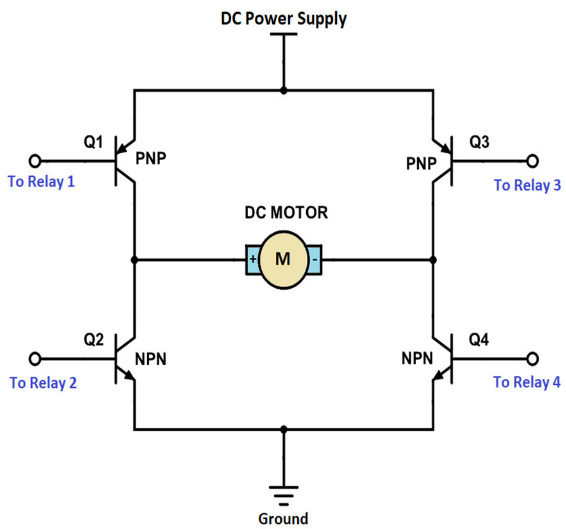

Figure 6. The H-bridge model used for the safe operation of DC motors in the system.

Table 2. Calculations used in the system for DC gear motors.

Quantity	Formula	Calculations
Electrical Power	$P = VI$	24 x 2 = 48 W
Weight	$F = mg$	15 x 9.81 = 147.15 N
Torque	$T = rF$	0.0832 x 147.15 = 12.24 Nm
Mechanical Output Power	$Pout = 2 * pi * w * t/60 = t * w$	12.24 x 2.5 = 30.6 W

A DC motor spins either backward or forward, depending on how to connect the plus and the minus terminals to the power supply. If H-bridge closes switches Q1 and Q4 then it has plus connected to the left side of the motor and minus to the other side. And the motor will start spinning in one direction. Since the transistor can be a switch, it'll be able to make the motor spin in either direction by turning on and off the four transistors in the circuit. Usually, low voltage drop transistor are used such as MOSFET and then diodes, resistors or Relays can also be used with these transistors for better protection. The calculations for DC gear motors are done by known formulas as given in Table 2.

H-bridge circuit is then designed in the software and later on PCB sheet for implementation on control circuitry as shown in Figure 7 in which 2 P-channel (IRF 9630) and 2 N-channel (IRF540) power MOSFETs are used representing Q1, Q2, and Q3, Q4 respectively. Usage of 2 P-channel and 2 N-channel in the H-bridge circuit instead of 4 N-channel because it provides better control (low power loss) and improves speed.

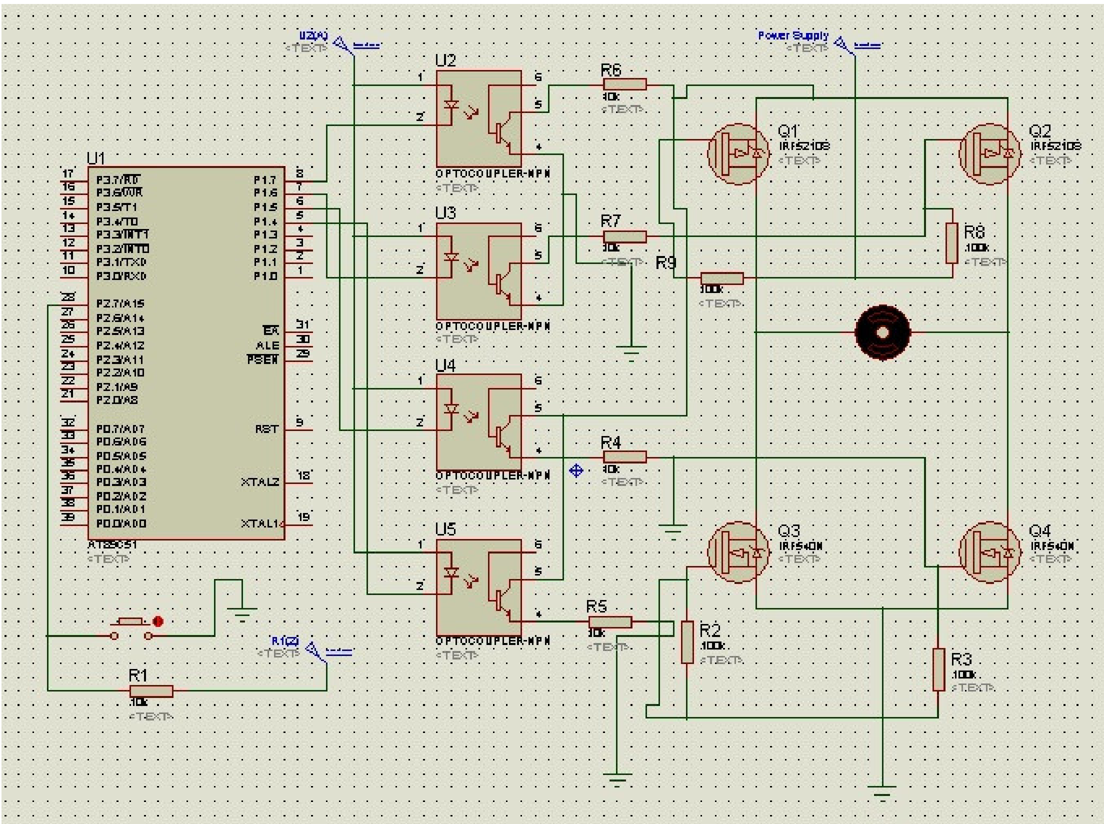

Figure 7. The Design and implementation of H-Bridge control circuit in PROTEUS software.

At the input side of the optocoupler, 5 V from a voltage source at one pin is to be provided and 0 V at the second pin from the microcontroller which actuates the gate terminal of MOSFET. Here optocouplers also provide electrical isolation which prevents from back emf. In this way, it can avoid the burning of the microcontroller. So when pulse gives to the gate of Q1 and Q4, the motor rotates in a clockwise direction and when giving pulse to the gate of Q2 and Q3, the motor rotates in the counter-clockwise direction. In this way, the direction of the motors can be controlled. For speed control of motors PWM (pulse Width Modulation) is done in this work. It is all about programming which is done into the microcontroller. Three-speed modes (Low, Medium, High) in the forward motion of the wheelchair are kept which provides low to full speed motion for providing some easiness to the end-user.

To control the speed ratio according head tilts, following commands are used "move", "1st speed" and "2nd speed". For user it is quite important to control the speed by decreasing or increasing it which is directly related to the angle. The command "move" makes the tilt angle to speed ratio from 0°–30° as 0–3 km/h wheelchair speed with 80 m/h speed for each degree change in angle. The command "1st speed" increases the speed ratio as; 0°–30° / 0–5 km/h with 160 m/h speed for each tilt's degree. The command "2nd speed" increases the tilts to speed ratio to 0°–30° / 0–6 km/h with 240 m/h speed. Figure 8 shows the graphical comparison between voice commands and tilt angle to speed ratio and this concept extracted from the research in [26].

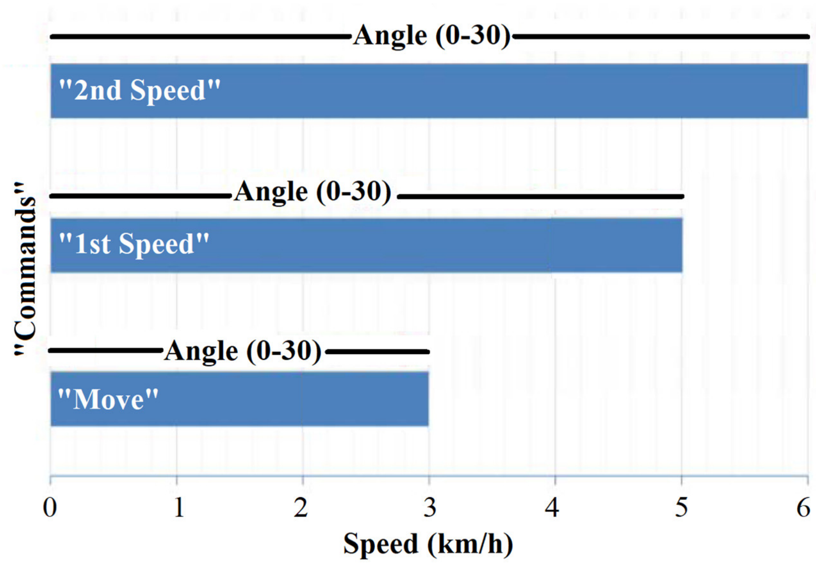

Figure 8. The graphical comparison between voice commands to the tilt angle speed ratio.

The ultrasonic sensor working used in the wired serial communication circuitry is shown in Figure 9 by using the flowchart description. This module consists of an ultrasonic transmitter, receiver, and a control unit. Whenever 12 V is provided to the circuit, then the ultrasonic sensor generates waves and transmits it. At the same time, these waves reflected from an obstacle. Here, the receiver receives waves and find total time which is taken for sending and receiving by calculating the distance between the object and the sensor. The microcontroller is used for processing and controlling the whole operations. Its purpose is that when the wheelchair is moving in the backward direction, the person sitting on the wheelchair can't see back, so this avoids any obstacle in the path by calculating the distance between wheelchair and obstacle [19,32–34]. In this circuitry, relay on the ultrasonic sensor actuates and the signal goes to the microcontroller which stops the wheelchair and then a person may go in any direction. The designed smart wheelchair in this research work has the following additional features.

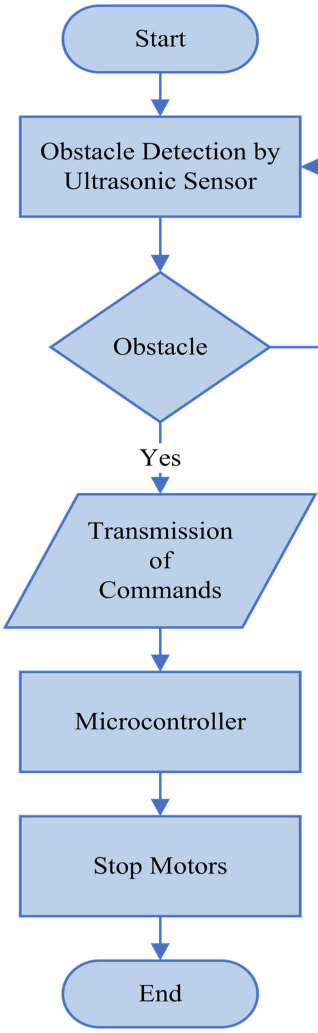

Figure 9. The working flow diagram for operations of ultrasonic sensor used in the system.

- ***The speed control for ramps***: When the wheelchair ramps up or down, the speed needs to be accelerated by natural balance because of gravity. In this way, for slopes or ramps, depending on the up or down process, the speed will increase and decrease, respectively. It is suitable for both forward and reverses modes [34]. Figure 10 shows the speed control process of the working system. Actually, this idea is proposed whenever a ramp is detected in front of wheelchair. The sensor will send the commands to the controller that the ramp/slop is upward so the torque and speed will be increased so that wheelchair can easily climb the slope. Similarly, the vice versa will be happened if the ramp slope is in downward direction.
- ***Reclining the wheelchair*****:** Constantly sitting in the same position is no use for the health of users. In addition, client comfort must also be considered. In this way, the choice of backrest continues to break the monotony and make it gradually satisfactory. Then, the back of the wheelchair can lean back in any situation according to the comfort of the customer.

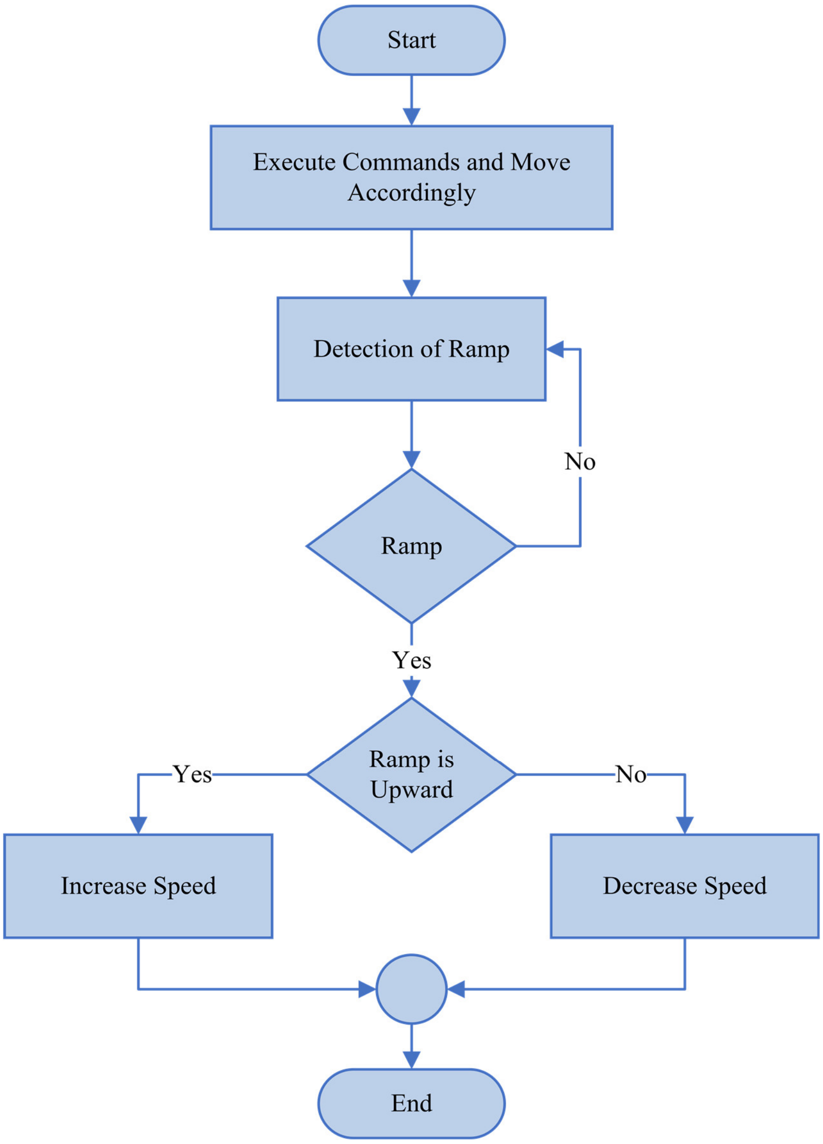

Figure 10. The working flow diagram of speed controlling in case of ramp.

- ***The control of lights:*** Users may need to move indoors or outdoors without light, or they may not be able to access the light due to a power outage. Under these conditions, the wheelchair will automatically detect a lack of light and light up naturally. Figure 11 shows how the component works.
- ***The control from a distance:*** When the user is not in the wheelchair, this component will help the user to control from a distance. The user can provide the commands from a specific separation, and the wheelchair will move according to the commands. This will eventually be useful when the user lies on the bed and the wheelchair has been removed from him [34].

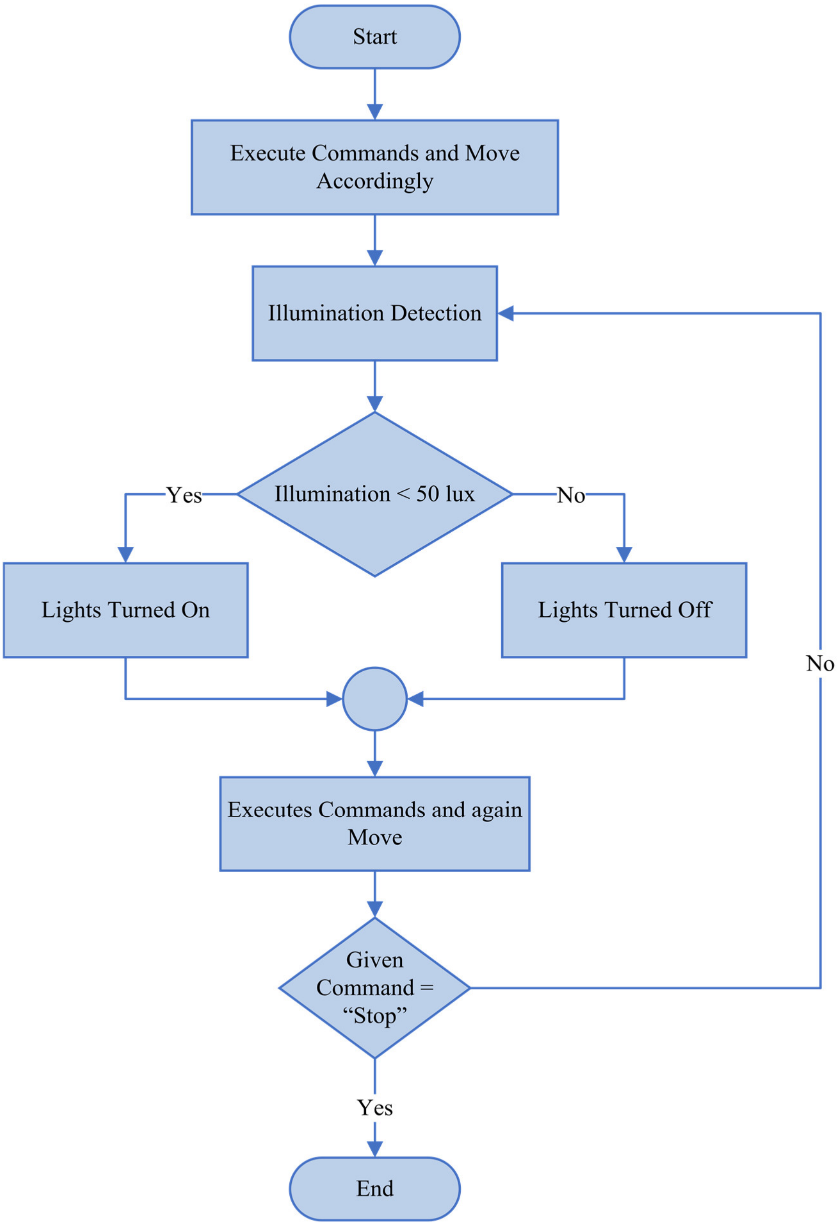

Figure 11. The working flow diagram of light controlling in case of power outage.

4. Comparison

A brief comparison of proposed smart intelligent wheelchair with previously designed wheelchair is presented in Table 3. The authors in [11] have designed the smart wheelchair by using the voice recognition methodology only. S. D. Suryawanshi et al. [19] and A. B. Satpe et al. [21] have completed the wheelchair by using an advanced method of obstacle avoider with having the voice recognition technology. Similarly, M. S. Sivakumar et al. [25] S. Priyanayana et al. [27] and M. I. Malik et al. [28] have designed the wheelchair by using the voice recognition methodology as the main factor of their research. In comparison with all these the proposed research work has the hybrid integrated features in the smart intelligent wheelchair as mentioned in the Table 3.

Table 3. The comparison between proposed research and the previous techniques.

Ref No	Voice Recognition	Obstacle Avoider	Ramp Detection	Light Detection
R. Chauhan et al. [11]	✓			
S. D. Suryawanshi et al. [19]	✓	✓		
A. B. Satpe et al. [21]	✓	✓		
M. S. Sivakumar et al. [25]	✓			
S. Priyanayana et al. [27]	✓			
M. I. Malik et al. [28]	✓			
W. Cao et al. [29]	✓			
Proposed	✓	✓	✓	✓

5. Conclusions

An intelligent healthcare system is introduced in this paper that can decipher client voice orders by partner separation-related vulnerabilities. The voice recognition system of particular commands in this research has also been successfully implemented in order to control the movements of the system. This intelligent system rehabilitates the diplegia associated persons or shortly who lost their upper extremities in an accident and helps them to live a normal life. Voice commands provide an easy interface because it is a way of natural communication and works with proper inputs even if there is a noisy environment around the user. Basic nine functions have been used to control the wheelchair movements in this work along with wireless control and successfully tested with the design. Wireless communication is done by the RF transmitter-receiver which enables to control the patient's movements by another person who's sitting somewhere else. The GUI interface is also designed and tested by using laptop and for android application development work is proposed for future. Environmental Light-up and ramp detection algorithms are also successfully integrated with the proposed design by using previous research. All these features depicted that an intelligent healthcare system is the need of current era for diplegia patients. Moreover, an ultrasonic sensor kit is used in the backside of the wheelchair to avoid obstacles from the back where a user/patient can't see. By using this system, a diplegia patient can control its movements in an intelligent or smart way which fulfills the objective of an intelligent healthcare system.

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Conflict of interest

The Authors declare no conflict of interest.

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