PID Sensor Controlled Automatic Wheelchair for Physically Disabled People

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Abstract:
Automation in medical mechatronics for physically disabled people has been researched in many institutes and various medical fields, and many scientists and researchers have developed a various prototype which is controlled by a gesture, RC, accelerometer, automatic control with the joystick in the functioning of a wheelchair for physically disabled people, but the control of the equipment using only PID (**Passive Infrared Detector**) sensor has yet to be developed. In this paper, we have mainly focused on the cost effective factor of developing a cheap automatic wheelchair for low-income families. This wheelchair works on the simple principle of a **PID SENSOR** as the Title suggests that the wheelchair is controlled using a **PID SENSOR** using **hand** obstruction so that the reflected infrared light falling on the PID sensor will give the received information to the Arduino board to give a signal to the motor to move the wheelchair as per the person's desire to the desired direction. We have mounted PID sensors for left, right, and reverse direction also. So, when the **Infrared sensor module** receives a reflected infrared ray to the **IR RECIEVER** then the reflected ray is initiated to give the signal from the obstruction of the OBJECT(in our case – **HAND/FINGER**) and thus the wheelchair starts to move. And for stopping the wheelchair simply take the obstruction made by the OBJECT (**HAND**) above the PID sensor then no infrared ray will be received by the **IR RECIEVER** then it will stop giving a signal to the motors to move any further and thus bring the wheelchair to a stationary position. So, this wheelchair design allows self-control using Infrared Sensors and a microcontroller (Arduino Uno) based circuitry. This design is to bring support for the physically disabled people with very low income who cannot afford to buy a fully functional automatic wheelchair at a high cost. The entire setup is done through a normal wheelchair with DC motors and a control unit consisting of IR sensors, Arduino Uno, beeper, motor driver modules, a switch, and a battery.

Keywords: PID sensors, IR sensor, motor driver module, DC motor, Arduino Uno, beeper, object (HAND), object detection.

Introduction

Physical disability is a great challenge in life to do any work and to maintain the same life throughout till our death. Now, the problem arises for the person who suffers it. Around the world, over the years the number of partially paralyzed people is been changing for a few decades. The census of 2001 [1] has revealed that 2.1% of the total population of India, i.e., 21 million people suffer from one or the other kind of a disability. Among the five types of disabilities on which data was collected, disability in movement or partial paralysis was 27.9% which was the second-highest percentage of the total physically disabled people. Full body paralysis or complete bedridden people are the most affected by this challenge. Among this 28% of the people come from very low or mild low-income families from rural areas. In the 1950s were the first Motorized wheelchair developed and thereafter many modifications were added newly as control mechanisms to provide the motorized control of the wheelchair [2,3]. Now, here is what our role explains, our aim with this research paper is to bring a cheap automatic electric wheelchair for partially paralyzed people, opening a new way to define and support their life by using this mechanism and prototype for giving them the ability to move freely. The research was based on the people who can't walk around with movement paralysis our main aim to tackle. The basic work in the prototype for this wheelchair is a set-up where the movement of direction is feed by the use of a NE555 comparator Passive infrared sensor (PID) and an Arduino Uno. It is connected with two motor driver modules and both modules are connected with one DC motor each. As mentioned in the abstract the PID sensors are responsible for the main movement of the wheelchair with the help of the programmable code pre-installed in the microcontroller which gives the signal to the motor driver modules and hence controls the speed and direction of the two DC motors. The other objectives of this equipment show the exact functioning of a normal electric-wheelchair with a perfect drive mechanism under normal conditions, and the wheelchair stopping and turning functions are the smooth and on-time activity that performs without any delay. Other than that the breaking actions on the wheelchair take place according to the sensor input by the user and give accurate results throughout the usage. Now those who serve private jobs with low income disabled by partial paralysis and can't afford a high-cost automatic wheelchair to move and work freely should opt for this mechanism and our prototype for working or doing their daily ablutions without any hassle. For, disabled people access to a wheelchair might be a human right but that's not the case in reality. Therefore providing wheelchairs that are accessible and affordable to everyone not only permits movement but also provides one the authority to lead a social & professional life with fewer barriers. The breakthrough of this design is an easy-to-understand easy-to-use design and a very reliable model to use because this is a new technology developed in a dedicated way for an automatic wheelchair to bring uplift in the field of medical mechatronics. So, overall this model is making the way for a new emergence of technology by using a fully IR sensor-based mechanism to control the direction of motors.

The paper outline is structured as a discussion for the previously done researches, inventions with a controller-based wheelchair done as the major aim from past years. Next, the Methods of our research and model have been explained in brief followed by the approach of the prototype with block diagrams for both of the explanations, and after that the System configuration and implementation are discussed further in the methods with the circuit diagram continued by working scenario with performance parameters in detail. After, that prototype 3-D designs are depicted further in the subsection following. The Results are then stated which is followed-up by the Discussion with limitations and finally, the conclusion and future scope of the model are explained

Literature Review

Automated wheelchair-using microcontrollers were first introduced in World War II for the injured soldiers at that time. The first control based wheelchair was developed in Marion Nursing home by Dugas [4] who is the medical director there and encountered falls from the wheelchair. On April 20, 1993, he patented a wheelchair with a lock system. In 2009, the wheelchair controlled by a joystick-model was invented by Thomas and Christian [5] that had various control features for sip-and-puff and the side-transfer acts by blowing the sensor. In, 2011, Fahad and Muhammad proposed a wheelchair model that was controlled by 3 fingers, where 2 of them are used for movement-control and speed-control [6]. Then came the preset-voice (start, stop, left, right) commanded wheelchair developed by Mazo, Rodrfguez, Urefia [7]. Also, in 2011 Tameemsultana and kali developed another hand and finger-controlled wheelchair, which worked on a flex-sensor (wearable on hand gloves) and an accelerometer (wearable on the head) which was controlled by the user [8]. In, 2013 Sukhmeet and Hem Chand from India designed a transistor of an accelerometer-based on 3-axis mems component along with an RF receiver-based wheelchair [9]. Then by mid-2016, Girish implemented the set-up of an IoT-controlled wheelchair that functions on movement along with an android phone [10]. Some other researches during recent times include review research by S. Siddiqui, Sampath SS, Mohammad asin, ET. Al. developed the design and fabrication of an Automated wheelchair for quadriplegic patients in the year 2017 [11]. Then technological advancements and research for newer variants of automatic wheelchairs were invented such as by using an Arduino microcontroller and GSM module- Paul Mathews, Anjana R Krishnan ET. AL. developed the Intelligent sides Electronic Wheelchair with patient monitoring technique for the concerned person [12]. In the same year, subsequent researchers were done to implement new technologies in Automatic wheelchairs Sumathi .D, Guru Prakash. S and Vibin Mammen Vinod developed the Brain-Computer Interface (BCI) based Smart Wheelchair Control [13]. The next research developed was by the use of a New Visual Joystick to control an Automatic Wheelchair in an Intelligent way by Yassine Rabhi, Makrem Mrabet, Farhat Fnaiech [14]. Then, a new type of Automation for a Wheelchair using a Hybrid BCI System was developed and researched by Vandana Akshath Raj [15]. Some other researchers did an up-gradation of the BCI based wheelchair by bringing EEG- Controlled Wheelchair: Using Wireless Network which was developed by Pranob Kumar Charles, Murali Krishna, Praneeth Kumar GV, and Lakshmi Prasad .D[16]. In, 2018 again C.N Sindhu reddy and K. Tejaswini developed a Voice-Based Automated Wheelchair using Wi-Fi [17]. In, 2019 Nadia Nowshin and Moontasir Rashid had developed an IR sensor-based automatic wheelchair-using eye blink technique with a GSM module for the safety precaution of the user [18]. Similarly, in the year 2019 various other researchers developed new techniques and found new ways to control automatic wheelchairs, therefore, Deepak Kumar, Reety Malhotra, and S.R Sharma presented the research on the Design and Construction of a Smart Wheelchair [19]. The Human –Machine Interface for a Smart Wheelchair was introduced by Amiel Hartman and Vidya K. Nandikolla [20]. Newer ways of controlling wheelchairs also included the Mobile Controlled Automated Wheelchair for Disabilities designed by Srinivasan Selvaraj, A. Ganasekar, Pacha Shobha Rani, and Dr. P. Ezhumalai [20]. Further developments again led to the App-based controlling of a wheelchair with other improvements in the monitoring of the person using the wheelchair such as the Android-based Automatic Smart Wheelchair researched by Varsha Pathak, Mrinmayi Pimple, Samiksha Jagtap, Rohan Awate [22]. B.D. Samran Alrashdi, K. Prahlad Rao, and Naif D. Alotaibi developed the Navigation of Electric wheelchair along with smart control [23]. Similar ways of design and fabrication of automated wheelchairs were done by R. sambasivam, C. Ranjit, T. Jerome, ET. AL, [24]. Then, in the year 2020 emerged a new concept of controlling wheelchairs through the "Eye-Controlled Wheelchair using Brainwaves with Home Automation and Alert" which helps a user to even control the home appliances through his brain the help of Brainsense [25]. Similar research was done by Mahmoud D., Muhammed E.H, Chowdhury, Amith Khandakar, Tawsifur Rahman ET, AL. and introduced An Intelligent and Low-Cost Eye Tracking System for Motorized Wheelchair Control [26]. Based on the above past researches/inventions and reviews, this research was carried out to build a system to move around automatically for people with disabilities in movement.

Methods of the research carried out

Brief working scenario of the prototype:

The model developed on our research and testing has a switch (ON/OFF) button with 4 IR sensors for the input with the Arduino Uno (the main controller) to control the direction of the wheelchair-using 2 motor driver modules. Here, the main switch is used to start the system for mobility then the wheel movement is directed by the object (hand obstruction) detected by each sensor to run the motors. And the power supply to the model is given through a lithium-ion battery with a charging facility (See

Figure 1).

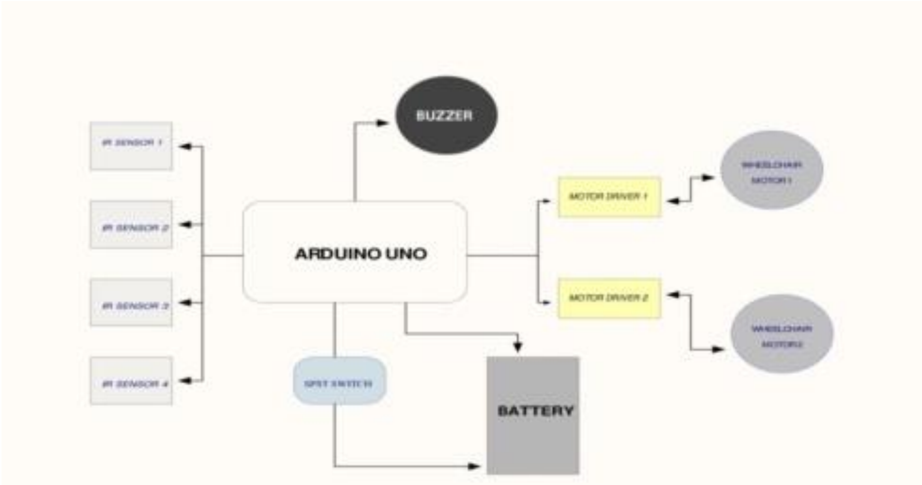

Figure 1 Block diagram for working process of the automatic wheelchair.

Block Diagram of the Mechanism:

The below-illustrated flowchart was followed, implemented and used for the design, and functioning of the model (See

Figure 2).

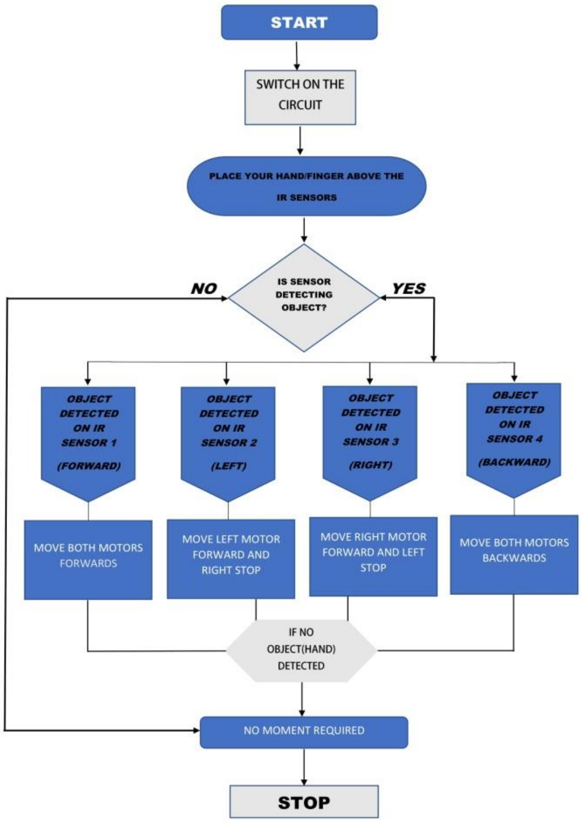

Figure 2. Flowchart for control of the wheelchair mobility and direction.

System configuration and Implementation:

In the designed model, the motor controller part which controls the direction of the wheelchair consists of 4 IR sensors; two motor driver modules, two brushed DC motor, an SPST switch, a beeper, and an Arduino Uno. We have used very sophisticated but reliable and low-cost IR Sensors and the DC motors used are good for electric powered automated vehicles such as this wheelchair with the best of the variant DC motor driver module to control the direction and speed of the DC motor. The circuit diagram for the control of the wheelchair is given below (See Figure 3). Using these components the input is given and a control prompt is initiated for the wheelchair. The detailed descriptions of the parts used are also listed below (See sub-sections 0, 0, and 0).

INFRARED SENSOR (KY-032):

The KY-032 is also known as the AD-032 sensor which is an obstacle avoidance/detection sensor it is a distance adjustable infrared proximity sensor that is designed to use with wheeled robots/electric vehicles. The sensor can be used to detect objects ranging between 2cm-40cm; it can be adjusted using the potentiometer trigger. So, the operating voltage of the sensor varies from 3.3V-5V so that the sensor can be used with microcontrollers such as Arduino, ESP32, Teensy, Raspberry pi, etc. The KY-032 is fairly accurate to sense changes in the surrounding environment and has strong adaptability to ambient light. This module has 2 infrared LEDs i.e., an emitter and a receiver.

DC MOTOR DRIVER (15S SMARTELEX 15A):

DC motor driver acts as an interface between the motors and the control circuit. The motor requires a HIGH amount of current whereas control circuits work on LOW-current signals. So to control the motors a motor driver is used to take a low-current voltage to convert it into a higher-current voltage that can run the motor. Here, we have used two 15S **DC motor driver module** to run two **24v DC motors** at 15Amp peak current. So, the motor driver module is acting as an H-bridge or relay to fill the gap, to generate higher currents from lower currents. The speed and direction of the motor are generated by two control signals from the motor driver modules. The PWM frequency is up to 32 kHz. It also supports TTL PWM from the microcontroller. Have an Internal thermal shutdown, under-voltage lockout, and PWM and direction controlled driving of four externally powered NMOS transistors.

24V DC MOTOR:

A DC Brushed motor is an internally commutated motor and a motor that can run from a direct power source. They were the first commercially important application of electric power to drive mechanical energy. In, our proposed model we have used two **24V DC brushed motor** to control the wheelchair movement. The energy which is generated by the rotor to the shaft is used to control the wheel movement. The 15S **DC motor driver** module is connected to the dc motors using jumper wires and, the single-channel switching state here initiates the Bidirectional motor movement for the four directions (Forward, Reverse, left, right) of the wheelchair.

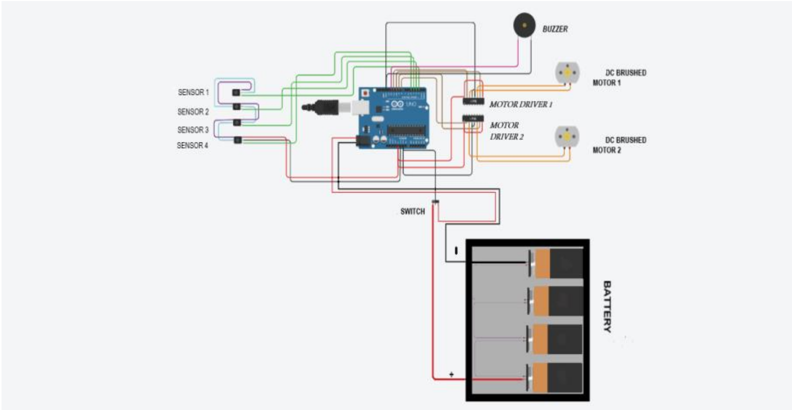

Figure **3**. Prototype circuitry diagram for motor rotation and movement.

Working Scenario in Detail:

The model version consists of an Arduino Uno, four IR **sensors**, two **DC motor driver modules**, two **DC motors**, a switch, and a beeper all fixed along with the wheelchair at different parts for the functioning of the model. To start the wheelchair, the user needs to switch on the circuit by switching ON the model from the right armrest, then to start the movement the user needs to bring his hand or finger along the way of the four IR sensors in the right and left armrest for the four different directions IR1F (forward direction), IR2L (left direction), IR3R (right direction) and IR4B (Back/Reverse direction) (See Table 1). The Motor driver is used to run the motor and to control the desired shifting of the motor movement connected to the wheels attached to the chair. Now depending on the object (**HAND/FINGER**) detected on each sensor the single-channel motor driver associated with one of the motors of the wheel decides the direction of the motor and also the direction of that wheel resulting in a movement. And the complete mechanism is controlled by the coding which is fed to the Arduino Uno microcontroller. And, the wheelchair is powered by a battery of lithium-ion. Furthermore, specifications include the buzzer which is mounted to give a sound signal whenever input is given. The 3-D CAD simulated model of the prototype is also represented below (See Figure 4, **Error! Reference source not found.**, and Figure 7). To compare with the other models and research work done by different scholars this prototype has various performance parameters such as the run time of the model can work along with up to 4 to 5 hours after a single charging of the battery. Then, IR SENSORS can work as long as it is used in a proper and safe environment. And, one can be reliable on this prototype to use it for a longer time span with regular intervals of maintenance and precautions taken. As discussed in the literature review some models may get unreliable to use and difficult to maintain but this model may not wear out as this prototype has lesser parts to make it run for normal conditions. No extra features were added to build up the cost. 24V DC motors are well efficient and run smoothly when under normal usage time. The 15S Smartelex 15A motor driver modules are smart and intelligent for the functioning of the motors efficiently throughout the run time. Adding extra features and modules to the main circuit can be done quickly as the microcontroller used here is Arduino Uno which is very easy to program and run for the entire process.

Table 1. Motor direction on object detected by each sensor.

HAND/ FINGER PLACED ON SENSOR-	**DIRECTION OF MOTOR 1**	**DIRECTION OF MOTOR 2**
IR SENSOR 1 (IR1F)	FORWARD	FORWARD

IR SENSOR 2 (IR4B)	BACKWARD	BACKWARD
IR SENSOR 3 (IR2L)	FORWARD	STOP/STATIONARY
IR SENSOR 4 (IR3R)	STOP/STATIONARY	FORWARD

3-D CAD design of the prototype:

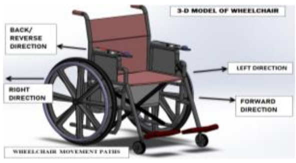

Figure 4. Prototype design 3-D model of wheelchair with movement paths.

Figure 4. Isometric 3-D view of the real model.

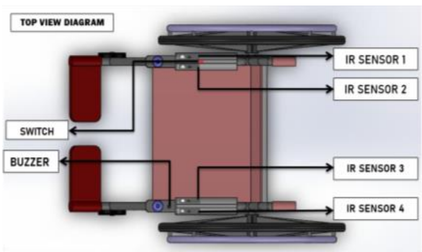

Figure 5. Prototype top-view design of wheelchair with parts.

Figure 6. Circuit diagram setup of the real model and working of the model.

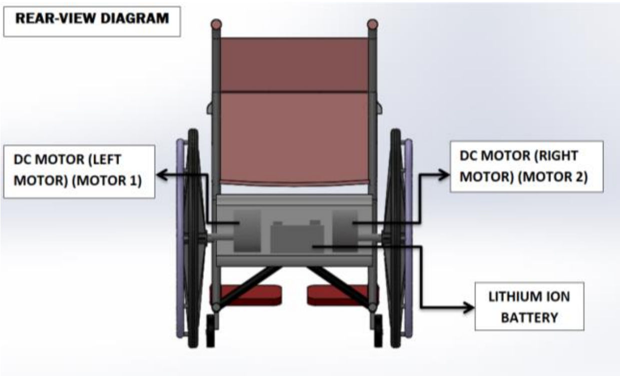

Figure 7. Prototype back-view design of wheelchair with parts.

Figure 8. Left side view of Automatic Wheelchair of real model.

Results

Along with the entire design and testing of the prototype our model was successful in various inputs and different terrain/environmental conditions. And based on the testing and outcome we can declare that our prototype can do the job of an ordinary automatic powered-wheelchair with very little cost as the parts used in the model are cheap and easily available in the market and a perfect mechanism to provide mobility to physically disabled people. As discussed above in the working scenario the run time of the model can work along with up to 4 to 5 hours after a single battery charge, IR SENSORS can work efficiently when under normal usage, also some wheelchair models may get damaged to use and difficult to maintain but this model may not wear out as this prototype has lesser parts to make it run for normal conditions. DC motors are well efficient and run smoothly when under normal usage. The motor driver modules are smart and intelligent for the functioning of the motors effectively throughout the run time. Adding special parts and extra add-ons to the main circuit can be done quickly as the microcontroller used here is Arduino Uno which is very easy to program and run for the entire process. Thus, our prototype is a new way of innovation for those who are physically disabled and immobile and cannot afford a costly automatic powered-wheelchair to travel from one place to another and give their lives support to bring physical mobility in their work and personal life. Hence, our aim of research for a low-cost automatic electric wheelchair has been successfully achieved.

Discussions

The prototype has got various limitations for a user as the major drawback of the IR sensor being used in Daylight conditions because the daylight use of IR sensor is limited due to the Infrared waves emitted by the sun and thus the IR used for the input can detect all the Infrared waves in the environment. And also the accuracy of the detection may cause trouble to the input given by the IR sensor because the frequency of the sensor may get affected by various environmental conditions such as smoke, dust, fog, and low temperatures [27]. And when the wheelchair is used for a longer distance then the hand or finger detected by the IR sensor may emit large doses of infrared waves and can also damage skin and tissues. So, that filtering the IR waves can be a solution, to avoid skin damage issues we can provide it with a glass covering above it, and also rectify the issue of accuracy and daylight usage we can place the sensor in a tube of black cardboard to use the sensor to detect in daylight. The comparative analysis of the prototype can be described as the following points:-

a) IR Sensor detection ranges for all four sensors were simulated from 0.5mm to 2cms.
b) In the real-time application, the IR Sensors detected the object (HAND) from 1cm to 5cm.
c) The distance traveled on simulation by the DC motors measured up to 10 meters on IR sensor when a high signal is triggered by the user.
d) On testing, the wheelchair can travel as long as 50 meters if the IR sensor detects an object (HAND) continuously.
e) On a Simulation basis, the high signal could take up to 0.52 milliseconds for detecting an object.
f) Whereas on real-time testing the time for detecting objects (HAND) even went up ranging from 0.5 to 1 second.
g) Voltage potential differences on both the DC motors were almost the same when the simulation test was done.
h) Voltage potential difference changed and showed different values on the testing of the prototype across the two DC motors.
i) No-load current or other heating issues were found while the real-time model was tested on the microcontroller or the motor driver modules.
j) Driver modules worked efficiently throughout the testing.
k) On simulation with various microcontrollers such as ESP32, Teensy, Raspberry pi, etc. the results for the output as well as the input-based circuits design showed no time difference or voltage difference across the testing process, with some slight changes in the distances traveled by the DC motors.
l) The Left and Right turn direction movement on simulation was accurate and perfect when the high and low signal was triggered by the user.
m) On real-time application slight variations on the turning position of left and right directions were achieved.
n) On simulation and the prototype testing both gave the same stopping accuracy when there was no object detection from the IR sensor.

All the above comparative analysis was achieved based on a load weight of a normal person weighing 75kgs. Cost comparison with the designed and modeled wheelchair was comparatively very less than the market price. (See)

Table 2. Cost comparison.

Designed and Fabricated Model of Automatic	Standard Automatic Wheelchair available in

wheelchair in INR	market in INR
Rs.12,520	**Rs.43,000**

Conclusion & Future Scope

To Sum up, our prototype is one of a variant in the present-day Automatic wheelchair types so by using the 4 PID sensors, an Arduino Uno, Two DC motor driver modules, and two DC motors the normal functioning of an Electric Wheelchair is best delivered efficiently to a person. The prototype is built with a microcontroller so including extra parts or features may require very small modifications on the main hardware like connecting the GPS, STOP button, Ultrasonic sensor, and ESC to the I/O pins of the microcontroller. For more stability, speed, torque we can replace the motors of the wheelchair with a 12V dc geared brushed motor as geared motors have smooth movement and provide good speed and torque. Also, in place of two single-channel DC motor drivers of 15A, we can use one dual-channel 15D for a 30A current load of motors to control the speed and direction for both the motors flexibly. And for those people who use it in household movement, the seat can also be made a detachable one along with the circuits and sensors water-proofed for bathing and other washroom purposes. Along with that, GPS can be added to track the user when the user is traveling for long distances and can be monitored by their family as to where the person roams around, with an Emergency STOP button for different situations and emergencies. Ultrasonic Obstacle avoiding sensors can be placed for the safety of the model wherever it travels. Hence, to control the speed of the motor, ESC (Electronic Speed Controller) can also be attached to the prototype.

Conflict of Interest:

The author confirms that this article contents have no conflict of interest.

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