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Control System by Voice for Autonomous Displacement of Blind People

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Abstract

This article aims to design and implementation of a wheelchair controlled by voice level that will allow visually impaired people through voice commands to navigate to a predetermined specific point in your home, displacement of the chair is given by defined paths which are determined by black lines on the floor. In this way people with disabilities can be mobilized in a safe and independent within the home.

Keywords: Microcontroller PIC, Rourter, Moto-reducers, Sensors, Voice Recognition.

INTRODUCTION

Around the world there are more than 37 million disabled people, accounting for 2 % of the world's population [1]. In Colombia, the number of disabled people exceeds 6.5% of the whole population (250 thousand Colombians [2]). This situation sets a dynamic problematic context that increases in complexity due to a lack of social responsibility together with preventative measures. According to the records of the city of Bogotá (Colombia) in 2007 [3], 70.063 people were identified to be suffering from permanent impairments, prevailing in 4.9% of the cases. These data indicate that disabled people are in need of technological mechanisms that help improve their quality of life. In Colombia, there is a wide variety of designs and implementations of devices intended to address the needs of disabled people. Some of the projects offer solutions to physical conditions such as paraplegia, quadriplegia, deafness, speech impairment. Other solutions address the physical impairments of Colombian soldiers injured in combat. However, there is a range of other application areas that have not been as explored, as suggested in the surveys reported by DANE. One of these unexplored areas is aimed at helping people with visual impairments. The purpose of the present document is to disseminate the findings of a research process intended to design and implement a scaled model of a voice-commanded wheelchair, which represents an attempt to offer a solution to disabled people, particularly those who suffer visual impairment. The idea is to deepen our understanding of such assistive technologies and innovate within our technological context, thus improving disabled people's quality of life.

This study applies a two-fold joint research approach, namely "qualitative-quantitative", since the starting point is a problem described by statistical indices, whose solution is based on existing proposals (projects). The prototype scaled development is divided into tour phases. Phase 1 corresponds to the construction of the wheelchair structure. Phase 2 is devoted to the study and implementation of devices that follow marks on the floor (lines). Phase 3 deals with writing the routing code. Last but not least, phase 4 corresponds to the study and implementation of a speech recognition system.

RELATED WORKS

Technological advances have taken place in countries like Japan and the USA regarding the use development of assistive devices, which benefit disabled people. At Universidad Distrital – Facultad Tecnológica – various degree projects in electronics have focused on speech recognition and most of these ideas have become prototypes; however, various limitations remain, that is, these prototypes offer reduced functionalities and their application do not address existing social problems.

In the construction of a wheelchair that offers extra functionality (that is, devices to facilitate people's mobility), many advances have been implemented, namely chair operation with either Joystick controls or voice commands; also chairs with sensors to avoid collisions.

The following is a list of existing works in the field of automatic wheelchairs.

The project called "Motor-driven wheelchair control system for quadriplegic" is system that consists of two motors and four contact-controllers, which are operated from a joystick by breathing in and out or by pressing buttons [4].

The project called "Adaptable control of a voice-commanded intelligent wheelchair" – Places great emphasis on controlling wheelchairs by using either a joystick or voice commands; additionally, there is an obstacle detector to avoid collisions with objects such as walls and doors [5].

The project called "Voice recognizer for an electric wheelchair" covers voice-command controls together with the navigation aids provided by "intelligent wheelchairs", which make use of sensors to identify and avoid the different obstacles found along the path of the chair [6].

In the project called "Wireless control system for quadriplegic people", there is a system that allows quadriplegic people to manipulate some of the most common elements of their daily lives by using radio-wave devices activated by blowing over an actuator or by using simple switches. [7].

The studies that are most relevant to the present proposal are those that offer research results about voice-command control, DC-motor control, speech recognition, and action response.

Other additional studies include the following: "Motor-driven wheelchair control system for quadriplegic people", "Intelligent wheelchair adaptable control operated with voice commands", "Electric wheelchair voice control", "Design and construction of an intelligent access command system based on speech recognition".

The present project uses a speech recognition module together with line-follower circuits in order to enable people with any type of disability (particularly visual impairment) to safely move around their houses.

METHODOLOGY

When making a prototype, five fundamental stages need to be considered Figure 1.

Figure 1. Execution blocks for the construction of a voice commanded wheelchair

In the construction of the wheelchair structure, we must consider the size of the base, the size of the structure and the type of wheels to be used. The second stage deals with the basic functions that must be performed by the chair, namely following a black line drawn on the floor; to do so, it is necessary to use CNY70 sensors. The third stage is about writing the routing code, which is what actually makes chair mobility possible; this gives the impression of having an autonomous chair that makes its own decisions. Stage number 4 is devoted to the design of the tracks upon which the chair will move. This stage involves aspects such as the material of he track; in this particular case, banner was the material chosen since it is easy-to-transport and also flexible when painting on it. Finally, stage number 5 involves using the elements already available in order to implement wheelchair movement and location. These elements need to be linked to the speech recognition system so that the chair performs its functions by responding to voice commands instead of conventional user code instructions Figure 2.

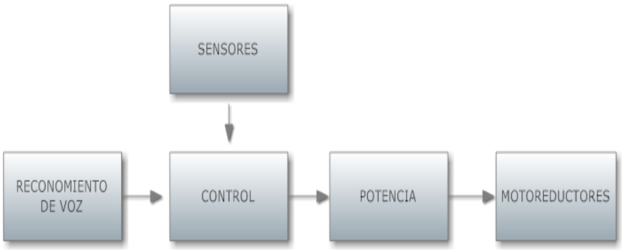

Figure 2. General Operation diagram

Stage 1: Wheelchair Structure Prototype

The wheelchair consist of a 30cm-long and 15cm-width base (a wooden sheet), which supports the modules that make up the structure, namely: gear motors, wheels [8], electronic circuits, battery, sensors, and the chair (Figure 3). The wheelchair prototype has been designed on a 1:20 scale, this scale was chosen because of the motor capacity in terms of weight. Since the amount of weight that the chair can carry is different from the tension applied to the chair, it is possible to implement weight control (tension); thus applying a tension level according to the weight load of the chair. However, this additional feature is not implemented in the present project.

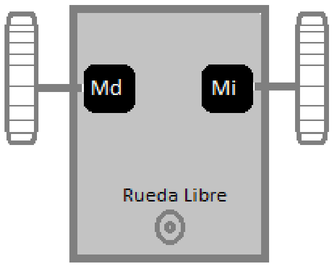

Figure 3. Wheelchair chasis

Electronic Circuit: the electronic circuit comprises (Figure 4) the control block and the power block. The control block includes a micro-controller that receives, processes and gives orders (namely 16F877A [9]) together with all sensors, the integrated circuit and the speech recognition system. The software package that served devices programming was "PIC-C compiler", which uses C language and permits writing well-structured programs by using functions, blocks or procedures [10].

The poser block comprises an integrated circuit, namely L293D, whose main function is to supply the necessary current levels for proper motor operation. This integrated circuit (L293D [11]) includes four circuits to handle medium-power loads, particularly small motors and small inductive loads; it can control current levels up to 600 mA per circuit with 12 V.

The L293D integrated circuit can then form two H Bridges that permit manipulating two independent motors. In this case,

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motor operation is made bi-directional, fast-braking and capable of easily implementing speed control.

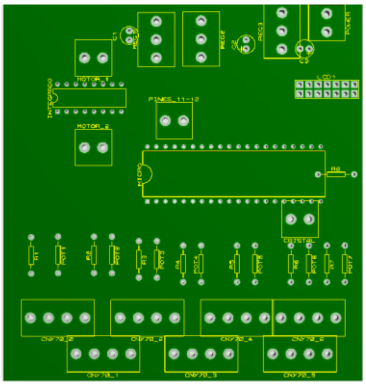

Figure 4. Electrical layout

Gear motors: the devices are 24-Volt DC motors, namely DME34535G-23G operating at 1863 rpm. These motors are made in Japan (Figure 5).

Figure 5. A motor with reduction gear box

Battery: battery MFYB2.5LC was used for this application. It is a dry-cell battery (Figure 6), which has a voltage of 12V and operation current of 5 A/h.

Figure 6. Battery

Sensors: the wheelchair has seven sensors (CNY70) lay on different positions so as to fulfill different purposes. Two of the sensors follow a black line, three sensors detect nodes, and two other sensors detect stations. CNY70 (Figure 7) [12] is a device that consists of an infrared LED that emits a light-beam and receives its reflection. Whenever the sensor encounters a black line and this signal is processed by the signal adaptation circuit (Figure 8), the result is a tension level between 0 V and 1.3 V (this value may vary according to the value of Rd – a variable resistor); this voltage is detected by the micro-controller as a low-level signal. Conversely, when the sensor encounters a white surface (or any other color different from black), the voltage values obtained may range from 1.6 V to 4.8 V, hence the micro-controller detects a high-level signal.

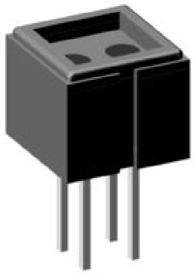

Figure 7. Sensor CNY70

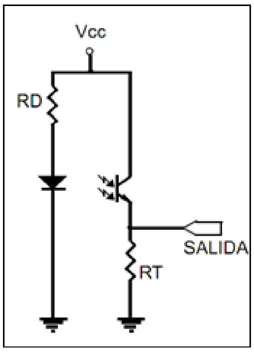

Figure 8. Signal adaptation circuit for sensor CNY70

Wheels: there are two big wheels at the back of the chair; these two wheels are attached to the gear motors by using two cylinders a con. To the rear, there is a free-wheel that allows the chair to steer.

The wheels are configured in a differential fashion since the possible changes in direction depend on speed differences between the two big wheels; hence, each wheel needs to be independent. The motors are linked to the wooden sheet by using tube-metallic clamps, which are properly screwed to the sheet itself.

Chair: the final part corresponds to the top structure of the wheelchair; this structure is the chair itself. Around this structure, there is a cover that overlays al components placed on the wodden base (Figure 9).

Figure 9. Chair external structure

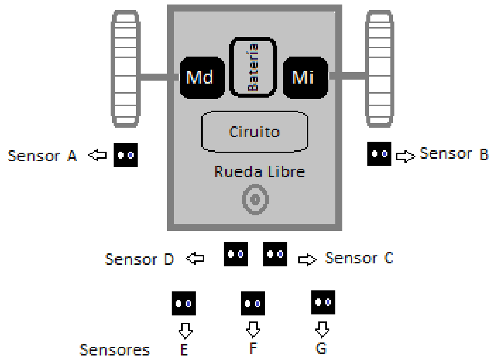

Figure 10. Element placement with respect to the wheelchair

Stage 2: Study and Implementation of Followers

As mentioned earlier, the wheelchair is equipped with seven sensors that perform the following functions:

Line-follower function: two sensors are in charge of this function, namely "Sensors C and D" (Figure 9). The sensors are placed to the rear of the chair (All sensors in this study are CNY70 sensors) [13] and are found right on top of the black line. When following the black line, the chair faces four possible situations:

Situation 1: In this particular case, sensors "C" and "D" are on top of the black line (see sensor position in Figure 9.); therefore, the chair itself needs no correction to its overall direction, that is, both motors must remain active. Ideally, in a long and straight path, if the chair is aligned and both wheels have the same speed, the chair must perform no corrections to its trajectory until finding a curve in its path.

Situation 2: In this case, the chair deviated slightly from towards the left of the black line and only sensor "D" is on top of the path line. The corresponding action is to turn off the motor on the right so that the motor on the left corrects the trajectory as appropriate.

Situation 3: In this situation, the chair deviated slightly towards the right of the black line and only sensor "C" is on top of the path line. The corresponding action is to turn off the motor on the left so that the motor on the right (still active) corrects the trajectory.

Situation 4: In this situation, both the sensors are off the trajectory. As a result of the code implemented on the PIC, the chair takes the last recorded data (before sensors were off-trajectory) in order to correct the new trajectory.

Node-detector function: to perform this function, three sensors located in front of the line-follower sensors are used, namely "E", "F" and "G" (Figure 9). The purpose of these three sensors is to detect nodes (places where the chair must make a steering decision). When two or all three sensors detect a black line, the PIC runs a node-decision program and so checks a data table that indicates which path should be followed (turning left, turning right or going past).

Station-detection function: the idea is to use two sensors, namely "Sensors A and B" " (Figure 10), each of them placed in front of a wheel, that serve to stop the wheelchair whenever it reaches its destination.

Stage 3: Routing Code

The routing code has three important parts. First, the code needs to acquire node information and station information depending on the number of possible destinations. Second, the code needs to know where to steer. Finally, the code needs to permanently check whether the bypassing station corresponds to its actual destination.

To start off, variables associated to origin, destination and hops are declared (origen, destino, saltos, consaltos, pn). Initially, variables are assigned the value zero so that there is no other value before the program starts running; additionally, the different functions are also declared in order to fulfill the following purposes:

Node-detector function: The aim here is to provide information regarding the number of nodes that the chair must pass before reaching its destination; also the number of hops (nodes plus stations) and direction that must be taken at the following node.

Follow-line: This function is about following the line while checking the stations and nodes that pass by; thus, depending on the information provided by the Route-table, this function will perform the corresponding actions, namely turning right, turning left, or going straight until reaching the desired destination.

Some other functions are also declared in order to reduce the length of the code. These functions represent possible states that might the prototype might execute.

- Turn-off (Apagado).
- Left (Izquierda).
- Right (Derecha).
- Straight (Derecho).
- TrajectLeft (Izquierdatrayec).
- TrajectRight (Derechatrayec).

Function of each variable: *A5:* This variable is in charge of starting the program. As long as this variable is equal to 0 zero, (logical zero), the program does not start.

S2, S3, S4: The function of these three variables is to indicate whether the chair is going past a node. Each variable is associated with ports A2, A3, A4, respectively. When the ports report a level corresponding to a 0-logical value, the variables take the value 1 and the sum of these three values must be equal to or greater than 2 so as to establish that the chair is actually at a node.

E0, E1: The purpose of having these variables is to indicate whether the chair is at a station or; when these two variables are logical 0, this indicates that the chair is at a station.

Origin, Destination: As suggested by their names, the values of these variables indicate the origin and destination of the chair at a particular moment.

Next-Node: This variable corresponds to an array (matrix) that is used to indicate the actions that must be taken by the chair at each node.

Hops: This variable is used as reference in order to know the number of nodes and stations the chair must pass by before reaching its destination, the value of such variable corresponds to the sum of nodes and stations.

Consaltos: This variable is used with the purpose of counting up (and increasing) while the chair moves forward passing stations and nodes; when this variable is equal to the value of Hops, it means that the desired destination is being passed.

Pn: This variable increases its value as the chair passes by a node; when this variable increases, it occupies a position in next-node. Depending on the value of next-node within route-table that an action will be performed (left, right, straight).

Code operation: The program initially declares the ports that will be used. Ports A, C, and E are declared as input ports, while B and D represent output ports. Ports A and E interact with sensors; C is (are) used for speech recognition; port B is the output for motor control and D interact with the LCD.

Subsequently, the code enters an unconditional "while" cycle. This cycle will permanently ask for the value of A5; when this value corresponds to "logic 1", the program is started, so inside the condition there is the value that will be assigned to the origin; this value corresponds to the four least significant bits. The destination value will correspond to the four most significant bits of port C. Subsequently, these two values enter the route-table, which is in charge of informing the system about the trajectories that must be followed at each node in order to reach the desired destination. The table also has information about the number of hops that must be encounter. Afterwards, the unconditional "while" cycle is left with a "break" instruction.

Once the algorithm is out of the previous unconditional "while" cycle, it executes the follow-line function (which tracks the black line) together with another unconditional "while" cycle that keeps asking the system about the number of hops. When the number of hops is different from the value of consaltos, the system will run a checkup (comprobar) function. At this point, the system uses the information about next-node contained in route-table together with the incoming value of next-node and of variable pn to take the different changes in direction that may occur at a particular node. Once these actions are executed, on arrival at the following node, there is an increment in both consaltos and pn, then next-node is no longer one but two, and so is consaltos. Of course, this type of increments depends on the origin and destination.

This processs will repeat until the value of consaltos is equal to hops, as the consaltos variable is being checked, the system will run the code section that corresponds to following the black line; when the values are equal, then the "while" cycle breaks, the unconditional "while" cycle is turned off and the system returns to the starting condition by using "goto", awaiting for the next destination to be assigned.

Stage 4: Path Design and Construction

At first, various drawings of houses and apartments were studied so s to choose one that had the most commonly repeated features. The chosen model corresponds consisted of three bedrooms, two bathrooms, a kitchen, and a common area for the living and dining rooms (Figure 12). In this design, users may have 8 possible destinations which must be established by drawing black lines on the floor (Figure 13).

Figure 12. Apartment floor plan

Banner was chosen as the material to build the tracks since this material is easy-to-transport and easy to paint. The dimensions of Banner sheets are 2.5 m x 3 m; these dimensions allow drawing the track so that nodes and stations are separated by suitable distances for chair mobility. The actual painting to draw the black lines was matt-black tempera since it produces no reflection of the infrared light emitted by sensors; hence, this is the right material for this particular application.

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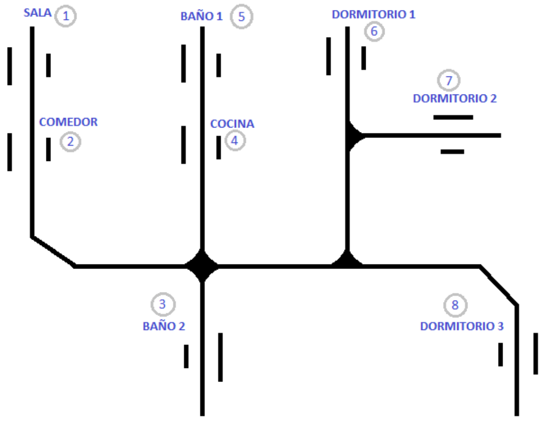

Figure 13. Track(s)

In this part of the process, a speech recognition module was used in order to make implementation easier (Figure 14).

Figure 14. Speech recognition device

This device is capable of recognizing up to 32 voice commands recorded in the following languages:

- English (EE.UU.)
- Italian
- German
- French
- Spanish
- Japanese

Communication: this device is equipped with a Tx output nd an Rx input, which can send and receive serial data (Figure 15). The device also has ports Vcc and GND to feed power (3.3v - 5v) [14].

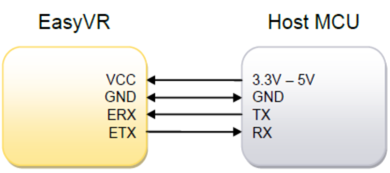

Figure 15. Data transmission

Serial communication in this case follows the Standard procedures defined in 1969 by the RS-232 standard (Recommended Standard 232), where voltage levels and data transmission rates are established (Figure 16).

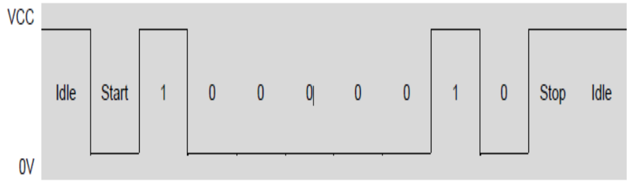

Figure 16. Communication protocol

RESULTS

Once the prototype was complete, various tests were conducted. In the experiments, voltage was varied from 9V to 12V while different weights and destinations were tested.

The position of the actual weight on the chair is very important because when weight unevenly distributed over the structure, the prototype losses speed when following the black line, also exhibiting larger error values.

The maximum weight that the chair bears with 9V is 4 kg. Tests were conducted with 5kg but the chair had difficulty in turning at node 3. Out of five tests, only in one occasion did the chair experience great difficulty.

Table 1. Tests conducted traveling from origin number 1 to destination number 5.

ORIGEN: 1				
Destino	Peso [Kg]	Tiempo [s]	Distancia [m]	Velocidad [m/s]
7	0	15,63	4,51	0,29
	2,5	18,83	4,51	0,24
	3	19,63	4,51	0,23
	4	25,48	4,51	0,18

In the process of observing the data obtained from the chair traveling to different destinations, origin number one and destination number 7 were chosen as sample path to analyze more speific results (table 1). When comparing speed vs. weight, it can be clearly observed that as weight increases, speed decreases gradually (Figure 17).

$$\mathbf{y = -\,0{,}0258x + 0{,}295} \quad (1)$$

As shown in Equation (1), the result was a negative slope that quantifies speed reduction to a proportion of 0.0258 with respect to weight.

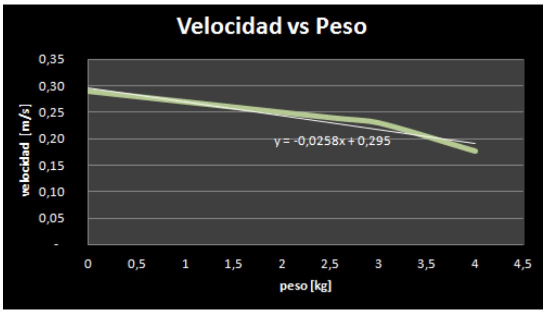

Figure 17. Speed vs. weight ratio

The behavior of the chair was compared in terms of speed variation in time. As expected, speed decreased as a result of weight (Figure 18).

$$y = -0{,}011x + 0{,}4522 \quad (2)$$

Equation (2) represents speed variation with respect to time. It can be observed that speed is inversely proportional to time; the longer the time, the lower the speed. On the other hand, it can be observed that the rate of change is equal to -0.011 with respect to time.

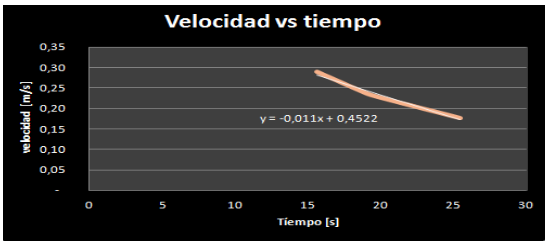

Figure 18. Speed vs. time ratio

The path on which the prototype requires more time to arrive at its destination using 9V is: origin1-to-destination7; the elapsed time in this case corresponded to 25.48 seconds, with a maximum weight of 4 kg; and 15.63 seconds with no weight (table 1).

The best operation range for proper chair performance using 12V was 6 Kg - 7 Kg. Only in this range can the chair fluently reach any destination. It was observed that if weight is less than 6Kg the chair's own inertia causes an unstable response, preventing the chair form smoothly turning and stopping at the different nodes. When weight exceeds 7Kg the chair has difficulty moving.

From Equation (3), an expected expression was achieved, provided that as voltage increases, the speed to arrive at each destination also increases, (Figure 19). From this follows that voltage is directly proportional to speed; however, the equation does not provide much information since the working range with 12V goes from 6 to 7Kg, and the working range of 9V goes from 1 to 4 Kg; ideally, tests needed to be conducted with fixed weights.

$$y = 30x + 3{,}9 \quad (3)$$

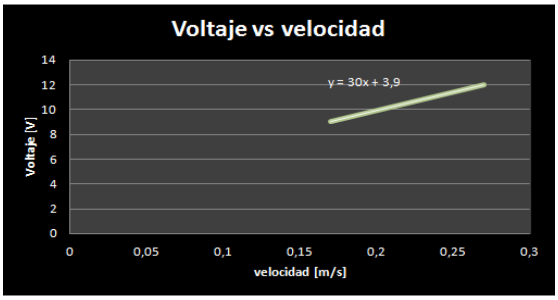

Figure 19. Voltage vs. speed ratio

It was found that the system requires only fine calibration for its varying base-collector resistor at night since external light sources produces shadows of the chair itself over the tracks, making the sensors detect non-existent black lines.

Tests were also conducted over different materials to draw the black lines. What was found was that materials such as black card or black insulation tape allow light reflection; hence sensors fail to detect lines from time to time; however, when returning to the painted lines (using matt black temper) the prototype follows the black lines with minimum error percentages.

CONCLUSIONS

A voice-commanded wheelchair with a line-follower mechanism can safely transport people with visual impairment since it accurately follows predetermined paths drawn on the floor.

This mechanism is capable of serving the mobility of disabled people suffering from paraplegia, quadriplegia, elderly mobility problems, and so on.

It should be possible to design black-line paths depending on the particular home needs of users; this might lead to source-code modifications.

The implemented routing code is an easy-to-modify algorithm, in other words, whenever more stations and/or nodes are required, only small portions of the source code should be changed.

In order to have a real-scale implementation of the proposed wheelchair model, apart from the physical chair, the only considerable adaptation lies in the power of the gear motors and its corresponding voltage source since the power circuits cope with voltages up to 32V.

The chosen battery is a CC since it makes speed control for DC motors easier. Additionally, this is a widely-used method in this type of engineering applications.

In order to increase tension (voltage) and so increase the weight load on the chair, a speed control that allows offering the required voltage levels for a particular weight range must be implemented.

Chair mobility is not as efficient when voltage levels or weight loads increase; moreover, if weight exceeds 8Kg, the wooden base that supports motors and the other blocks (modules) might crack or even break altogether.

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