USER INTERFACE AND NAVIGATION SYSTEM FOR AN ELECTRIC VEHICLE FOR THE DISABLED.

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ABSTRACT

The purpose of this work is to link a natural user interface and an autonomous navigation system to a conventional wheelchair with two control modalities: manual and automatic. It is taken into account that not all people have the same type or degree of disability, for this reason we seek to implement a user interface that involves different forms of user-machine interaction, with which the user can choose the manual mode that allows direct commands to control the movement of the chair and the automatic mode, which only needs the point or place where you need to go and through predefined trajectories, the autonomous navigation system will execute the necessary movements for the chair to follow the desired route.

KEYWORDS

control, electric vehicle, control, autonomous, control loop.

1. INTRODUCTION

The World Health Organization (WHO), in a report on people with disabilities, mentions that more than one billion people live around the world with some form of disability, 200 million of them have difficulties with their movement. These people have many accessibility limitations to many of the services that a person without disabilities might consider very necessary or obvious.

Motor disability is the difficulty that some people have in participating in activities of daily life, which arises as a consequence of the interaction between a specific difficulty in manipulating objects or accessing different spaces [1]. In recent years, technology has made dizzying progress in its various branches of study. Regarding this project, artificial intelligence and robotics have given humanity the ability to carry out tasks in an effective and autonomous way.

A large section of robotics and artificial intelligence applied to aid for the disabled is aimed at the development of smart wheelchairs [2]. These innovations aim to raise people's quality of life in such a way that the wheelchair user avoids the need to control every advance and turn of the chair during the journey, allowing them to simply sit and relax while moving towards the destination. place that the user sends.

2. VEHICLES FOR THE DISABLED

Autonomous wheelchairs significantly support the user, allowing obstacle voidance, in some cases autonomous navigation, among others. Autonomous wheelchairs are conventional chairs that have been equipped with computer systems and sensors; The sensors capture the environment and the state of the chair, they send signals to the controller and it processes them to execute the tasks

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specified in the programming [3].

Although this project does not exactly use said concept, “autonomous wheelchair”, its functionalities apply very directly to it, since a conventional wheelchair will be instrumented with a computer and sensory system, so said project will finally have a product which can be considered as an autonomous wheelchair, however, it will have two modes of operation, manual and automatic. Mobile robots, in this case wheelchairs, can be based on different platform designs, which are differentiated by the various traction systems they use. The differential traction system is the one that will be used for the prototype since it is one of the most used; Furthermore, to motorize a conventional wheelchair it is the easiest traction system to implement. A differential traction system uses independent motors for each wheel, but located on the same axle, and also uses idler wheels or support points to provide stability to the platform [4]. have proposed a diagram of a conventional wheelchair motorization system (see Figure 1).

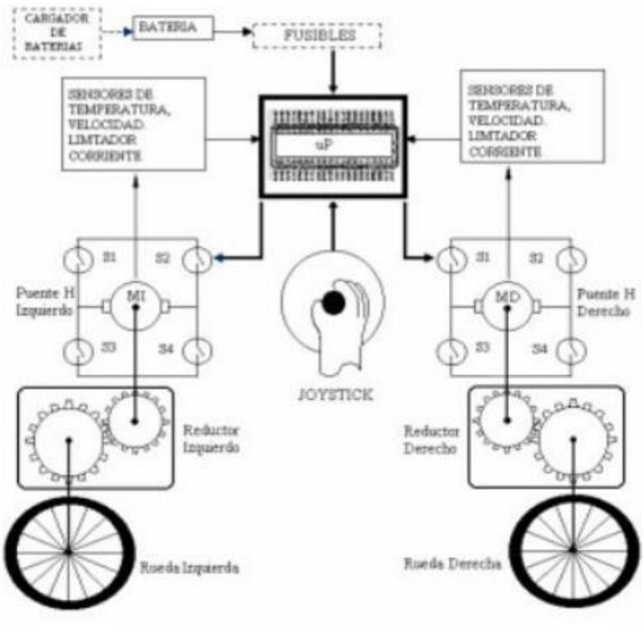

Figure 1. Wheelchair motorization diagram

According to the diagram, the motorization of a wheelchair involves a control system that receives controls from a manual joystick and consequently manipulates the motors to carry out the action. The traction system used in said diagram is the differential [5].

The desirable features for an autonomous wheelchair are the following:

1. Easy and, if possible, automatic action on the movements of the chair, obeying in any case the user's wishes.
2. If possible, move between two locations specified by the user without the need for subsequent interventions or route corrections.
3. Travel at normal speeds, taking the maximum speed to be 5-6 km/h and the minimum speed to be 1 km/h.
4. Safety: avoid any accidents, whether due to collisions with fixed or other mobile elements or falls.

On the other hand, a descriptive study of the problems of people with motor disabilities must be carried out for the development of a wheelchair control project [6], in order to have greater coverage of the needs of the patients. potential users of the chair and suggests the following methodology.

1. Identify the needs of the object of study.
2. Devise and carry out solution options to the needs of potential users.
3. Study the technology of mobile devices and the interconnection via Bluetooth between the device and the controller (hardware).
4. Adapt the accessories to the wheelchair (sensors, batteries, motors, among others).
5. Develop the control program.

Another important point of the project is to give the user, in manual mode but mostly in automatic mode, the opportunity for the vehicle to avoid impacting seasonal objects (walls, planters, among others) and temporary objects (such as people). , various objects, among others).

Mobile robots, which have one of their functions to detect obstacles [7], use a series of sensors to obtain the necessary information from the environment around them to be able to interact with it. The basic operation of ultrasonic sensors as distance meters has a receiver that emits an ultrasound pulse, which bounces off a certain object and the reflection of that pulse is detected by an ultrasound receiver.

There are factors inherent to both ultrasounds and the real world, which have a decisive influence on the measurements made. Therefore, knowledge of the various sources of uncertainty that affect measurements is necessary to be able to treat them appropriately.
To carry out all these processes, robotics has resorted to control systems, which are those dedicated to obtaining the desired output of a system or process. They are mainly classified into open-loop and closed-loop control systems (Figure 2).

Figure 2. Diagram of a closed loop control system.

As has already been said previously, the traction of the wheelchair prototype will have different traction, which below will show the basic aspects that must be considered for the modeling of this system. It starts from a diagram in an xy plane with a vehicle from which the center of mass is taken (Figure 3).

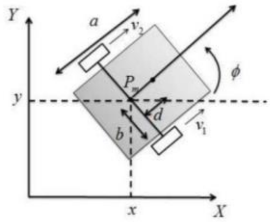

Figure 3. Generalized diagram of a differential mobile robot.

Kinematic model proposal:

$$\dot{x} = v * \cos(\theta)$$
$$\dot{y} = v * sen(\theta)$$
$$\dot{\theta} = w$$

The kinematic model is given by the previous equations, the variables of interest are v and w since these are the inputs to the system. "However, the linear speed of the robot and the change in direction of the vehicle are obtained by the change of left and right angular velocities, wi and wd, corresponding to the speed of the wheels [1]. It is then possible to modify the equations to find the relationship between v and w and the angular velocities wi and wd. In this configuration, only the two front tires of the mobile robot are considered and it is assumed that a force Fi and Fd acts on each one, providing the linear velocities of the fulcrum of the wheels, vi and vd, respectively. Note that the system is nonlinear, as it contains sine and cosine functions in the kinematic model, so linearization is necessary for input-output decoupling. This type of linearization is known as input-state linearization. A nonlinear system of relative degree r characterized in terms of vector fields and directional Lie derivatives is given of the form:

$$\dot{q}=f(q)+g(q)u$$
$$y=h(q)$$

Where "h" is the system output, "q" is the state vector and "u" is the control input. The exact linearization procedure begins by differentiating with respect to time to "y" successively until at least one control input appears. Once the control output(s) is made explicit, the highest order derivative will then be the relative degree of the system, which must be met:

$$yr = Lf\ rh(q) + LgLf\ r{-}1h(q)u$$

Con

$$LgLf\ r{-}1h(q) \neq 0$$

Since the first r-1 temporal derivatives do not depend on the u control, it must be satisfied

$y = h(q)$
$\dot{y} = Lfh(q)$

Also being fulfilled

$$L_g h(q)=0$$
$$L_g L_f h(q)=$$
$$\vdots$$
$$LgLf\ r{-}2h(q) = 0$$

The smart chair has sensors that capture the environment, computer equipment that processes the information and, together with voice recognition, allows the user to verbally order the place they want to go and the chair autonomously executes enough movements to reach the desired point. . This article will serve as a reference for this project since it has two similar characteristics: human-machine interaction through voice commands and autonomous chair guidance. In which the design on which they are based reduces the price of commercial motorized chairs by 50% in addition to preserving their classic functionalities: folding and manual traction.

As a result, it was obtained that the control system, the sensors and the audible alarm function correctly and within expectations. Although this article from the University of Entre Ríos uses manual control using a Joystick, it will be taken into account for the project since it will serve as a basis for one of the objectives: the motorization of a conventional wheelchair. As a national reference, a scientific article was found that bears the title "Control of a wheelchair through a mobile device with Android Operating System." In which José Mancilla, Héctor Crespo and Néstor Morales, students and teachers from the Tuxtla Gutiérrez Institute of Technology present an electronic device adapted to a wheelchair to motorize and control it through a mobile device with Android OS. As a result, the DC motors responded correctly to the manipulation of the graphical interface of the device with Android OS. From this research, the part of the creation of the graphical interface for devices with Android OS will be rescued, in addition to the methodology that was used for the problems that people with motor disabilities have when moving around.

3. PROTOTYPE

Because our purpose is an experimental prototype, we sought a way to build a low-cost wheelchair that would be in accordance with the needs of the project and the materials available for its realization. Among the materials that were used were PVC pipe (schedule 80), PVC accessories (90 connections and T schedule 40), 18mm plywood, screws and machine tools such as a drill and screwdriver. Using CAD design software, a virtual prototype was designed (Figure 4), to obtain the necessary amount of materials and to make the cuts and assemblies when physically building the prototype.

Figure 4. Digital electric vehicle prototype.

The instrumentation of the chair is divided into 5 parts: power, actuators, sensors, controller and communication.
The energy part is divided into 2, power for the electronic part and power for the motors; For the electronic part, a 11.1V to 2200 mAh LIPO battery is used and for the motors, 2 batteries connected in series of 12V to 4 Ah, which result in 24V to 4Ah.
As actuators we have 2 20 Kgcm reducer motors that operate with 24 volts at 1 A. for maximum load. Because there is no table of characteristics, these are unknown and we only have approximate data about them.
It is the central device of the system, it receives signals from sensors and secondary devices to execute commands to the system's actuators, in addition to communicating with the user interface.
It is the board where the system's sensors and actuators are connected, as well as the development boards.

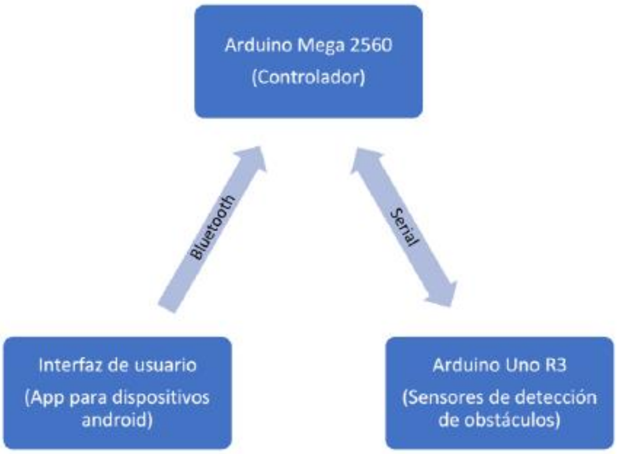

Figure 5. System communication scheme.

Kinematic modeling

The equations of motion of a differential robot have been a widely studied topic over the years, based on equations 4, 5 and 6 in the theoretical foundation section [1], it shows that the equations of motion are the following :

$$\dot{x} = v * \cos(\theta)$$
$$\dot{y} = v * sen(\theta)$$
$$\dot{\theta} = w$$

Even with these equations, it is necessary to break down the speed v, so the following equations of motion are proposed for a differential mobile robot:

$$\dot{x} = \frac{r(w_d+w_i)}{2} * \cos(\varphi)$$

$$\dot{y} = \frac{r(w_d+w_i)}{2} * sen(\varphi)$$

$$\dot{\varphi} = \frac{r(w_d-w_i)}{2l}$$

Proposal for A Controller for the Differential Mobile Robot.

Once the equations of motion of a differential traction mobile robot have been obtained, the next step is to propose a control technique that allows the tracking of trajectories desired by the user, see equation 20.

$$\frac{d}{dt}\begin{bmatrix} I_a \\ \omega \end{bmatrix} = \begin{bmatrix} -\frac{R_a}{L_a} & -\frac{k}{L_a} \\ \frac{k}{J} & -\frac{B}{J} \end{bmatrix}\begin{bmatrix} I_a \\ \omega \end{bmatrix} + \begin{bmatrix} \frac{1}{L_a} \\ 0 \end{bmatrix} u$$

The control law is given by

$$u = \left[\frac{JL_a}{k}\right] u_{aux} + \left[\frac{BL_a + JR_a}{k}\right] \dot{F} + \left[\frac{BR_a}{k} + k\right] F$$

$$u_{aux} = \ddot{F}_d - \gamma_2\left(\dot{F} - \dot{F}_d\right) - \gamma_1(F - F_d) - \gamma_0 \int (F - F_d)$$

4. RESULTS

Regarding the instrumentation of the chair, sufficient devices were installed to carry out the necessary experimental tests to be able to define the results obtained (Illustration 8 Instrumented physical prototype.); One of the points to highlight is that the prototype only worked without a crew member, because the maximum torque provided by the motors would not withstand such force, for that reason, the control joystick was placed in the rear part above the chair, to facilitate prototype testing.

Obstacle detection carried out from the Arduino Uno R3 with the use of ultrasonic sensors, detects them whether static or moving, at an average distance of 1.5m, sending a signal to the central device (Arduino MEGA 2560) which is responsible for stopping the motors before hitting the obstacle, resuming its movement when receiving the signal that the path is clear, changing trajectory or changing from autonomous to manual control. It is worth mentioning that obstacle detection works only in autonomous mode.

A very important point for the safety and comfort of the user is the soft start and stop of this, in which good results were obtained. Below are two graphs of the software simulation of the method based on the monitoring of a velocity trajectory using a 3rd degree Bézier curve (Figure 6 and Figure 7):

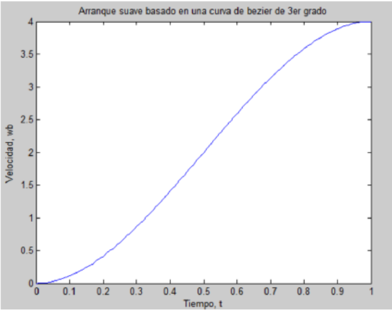

Figure 6. Soft start based on Bézier curve.

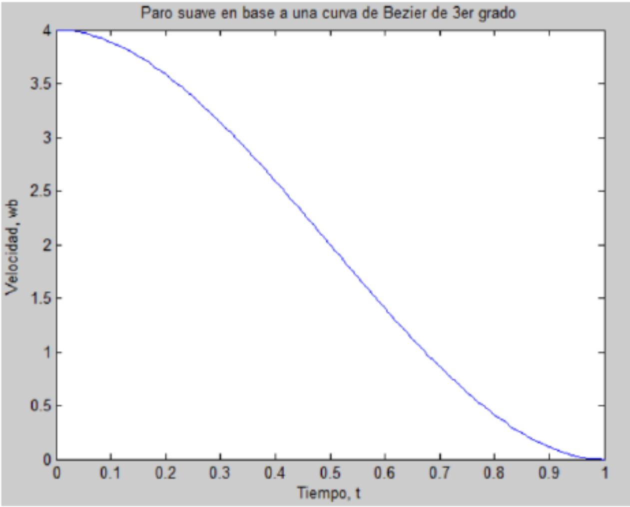

Figure 7. Soft stop based on Bezier curve

The controller designed for this system has a high degree of complexity to be executed on low and probably medium range microcontrollers, and by not having better quality devices, the implementation of this controller in the wheelchair was impossible, but, obtained good results in simulation in the MatLab Simulink software. For future work, the use of more powerful microcontrollers is recommended to implement the proposed control, which will surely obtain better results.

Using a closed-loop control system, a basic implementation was produced for trajectory tracking (in this case, a physical line), adding a PD controller seeking greater reliability and security for smooth and precise line tracking, obtaining results quite good, in which the user orders the destination they want to go to (point B or point C) and the chair moves autonomously until the order is fulfilled, controlling the speeds of the motors without the user intervening directly.

The application designed, see Figure 8, for devices with Android OS was developed in a simple way in such a way that it is sufficient for this experimental stage of the project, but it is not a fairly intuitive and effective application if what is sought is to take it to the public or market.

Communication between the application and the central device was achieved quite reliably and safely, successfully sending the necessary data for the chair to make its movements based on what the user orders from the application.

The prototype remains working and at the disposal of the electromechanical academy for future work, in order to achieve improvements in aesthetic and functional aspects; such as control methods, power supply of the electronic and power part of the chair, forms of user-machine interaction, etc.

The project is in the testing and adjustment phase, so we have concentrated on the equipment and instrumentation of the chair rather than on the ergonomics and appearance of the prototype, where the Joystick and was placed on the right arm support, provisionally. In the case of the graphical interface and the application, the APP INVENTOR MIT was used, which is intended to move the chair from point B to point C (see Figure 8). The next step is to insert cameras for navigation with obstacle detection, in addition to starting to use the “Python” language for programming routes and trajectories.

Figure 8. H-M Communication App User Interface.

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