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MECHANICAL PROJECT AND CONTROL OF ROBOT GUIDELINES FOR VISUAL DISABILITIES

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Abstract. This paper proposes the mechanical design and the trajectory control of a mobile robotic system applied to the displacement of the visually impaired in physical facilities IFPE Caruaru. The movement of the automatically guided systems is based on the study of the different techniques of generation of existing paths and methods of evasion of obstacles, which use different types of algorithms for the control as part of the system of direction and navigation of the system. The idealization of the system involves designing roadmaps, paths and determination of the following trajectories, which depend somewhat on the configuration of the machine. The study of the different configurations for the paths planning should consider a previous knowledge of the physical plan of the layout in simple line. Among the specific objectives, it is intended to select a suitable microcontroller for application, as well as to assemble the embedded system (microcontroller system and power circuits for direct current motors), to study and select among the orientation methods, the most suitable for applicability , to program in C language an efficient firmware, so that the microcontroller can execute the PID control of speed, generation of paths and obstacle avoidance, and finally devising a destination choice with man-machine interface through application voice command on Smartphone. For cost savings and applicability of independent electromechanical structure, the mechanism control is set in the application, and the embedded system will only be the receiver and executor of control signals through Bluetooth communication.

Keywords: prototype, trajectory control, guide robot, remote control, visual disability.

1. INTRODUCTION

The constant search for improvements to society through technological development instigated the research group to develop a prototype which would help people with visual limitations in their daily activities. The idea began with the realization that 23,92% of society lives with some kind of physical, mental or intellectual limitation (according to the 2010 Census) and there is a variety of equipment that helps in their daily lives. Visually impaired people lead this group of people with 18,6% of the total population and are commonly neglected. Mobility and autonomy are not the only difficulties in the daily life of this part of the population, access to knowledge, education, work and other forms of social interaction (Luiz, Rosa and Pftscher, 2012).

Dog training guides were created by the government in order to improve the living conditions of the visually impaired. However, the realization of this enterprise requires a certain amount of time for the animals to be trained, as

well as daily maintenance costs with food and health. There are also several factors that limit the use of these animals, such as society's poor understanding of dog work. They are often forbidden to enter public or private spaces, even with the existence of laws guaranteeing this right. There is also a demonstration of affection for the dog by people in the surroundings that distract the animal from the work. In this way, the development of a prototype that helps people with visual limitations becomes an alternative to the use of these animals. The attributes of a robot when performing the tasks are of the most varied, from the decrease of the cost of acquisition and maintenance to the possibility of mass fabrication of the model.

Currently, the researches of development of projects in this line of research are under development in several countries. In the United States, researchers at the Georgia Institute of Technology developed a guide autonomous robot for the possible replacement of a guide dog (Technological Innovation, 2015). In the neighboring country, post-graduate students at the National Polytechnic Institute of Mexico (IPN) are developing a guide robot called Amepique operating on three algorithms: one to deflect obstacles, another to simulate the behavior of a guide dog, and a third party that recognizes signs in public places so that it can advise the user of the location of the bathrooms, evacuation routes and safety zones (Acerco, 2015). The National University of Pulsan located in South Korea presents a wide development about a guide robot. Wei, Kou and Lee (2013) and Wei and Lee (2014) report the creation and optimization of the prototype based on a Fuzzy controller for human-machine interaction and trajectory generation. In the works, the methodology is implemented through a mobile application (robot control and human-machine interface) that uses the camera to analyze situations in urban environments. The research found in Brazilian territory, mostly, focuses on the development of sensors for the robot guide, not having control of trajectory in a given space. This is due to the focus on external environments such as the Lysa robot owned by Vixsystem and graduate student Stênio Oliveira (2014) by Federal University of Pernambuco.

Other research that includes the creation of robot-guides for closed environments with the plant identification, are presented at initial levels. In this context, the research by Barros *et al.* (2015) of Federal University of Pernambuco and Muñoz *et al.* (2010) of the University of Brasília.

The realization of this project makes the use of technological tools function of the beneficiation of the visually impaired. The robot, titled D.O.G. (Guide Guiding Device), seeks to be more than an obstacle alarm element. The project contemplates guiding the user with total autonomy within a closed establishment, and thus, to optimize accessibility objects.

2. METHODOLOGY

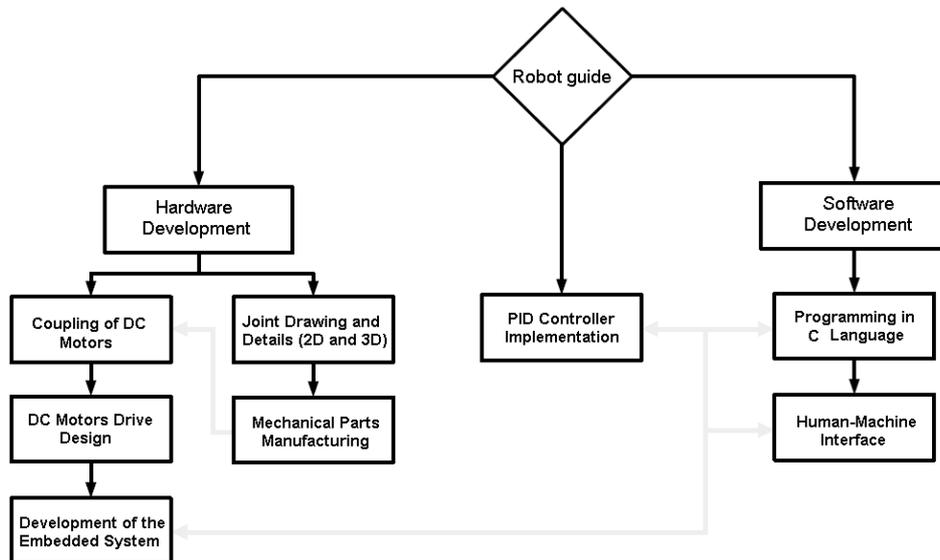The prototype design was structured in some steps, as shown in Fig. (1).

Figura 1. Methodology for the D.O.G. project. Source: Author.

The development of the project was initiated by the layout of its operating structure. The first step was to define the trajectory control that should be used. According to Choset *et al.* (2005), one of the fundamental problems of autonomous robotics is the realization of the path where obstacles present in the environment are avoided. There are two general classes of wireless orientation methods, the first is wirelessly referenced on the ground. The advantages of this technology are its flexibility and easy installation. They may be optical or painted chemical lines. The second class is wireless and referenced in the plant, being divided into four types using different measurement methods. The first is

the dead calculation method that normally uses odometry. The second method is the laser beam that uses several scanners to send rays of light to form the trajectory stretch. The third method is the combination of the dead calculus and the laser oriented ones.

The fourth method is the obstacle bypass system, by means of a series of reference positions along the space. Thus, in view of the existence of a large bibliographical quantity and a better access for research, it was decided to adopt the line guidance system on the floor in the D.O.G. within the facilities of the Federal Institute, allied to presence sensors to identify fixed or mobile obstacles during the path traveled by the robot obeying the following control flow chart shown in Fig. (2).
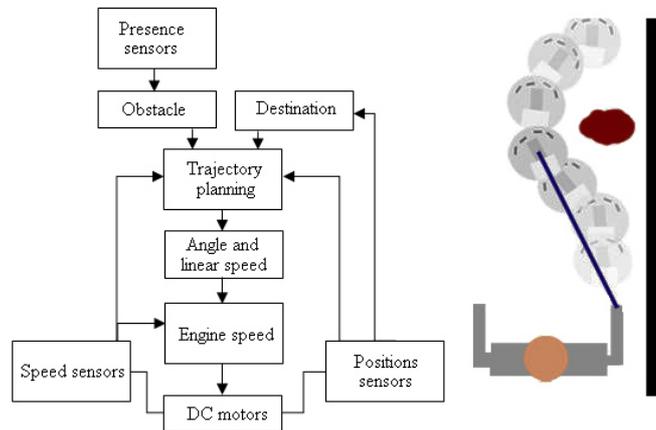
Figure 2. Proposed flowchart for the control of the robot guide. Source: Author.

The average speed of a human walking is approximately 5 km/h. The established speed of the robot must be less than this value, because this is a strategy created so that the people of the enclosure can have the reaction to divert the disabled.

Spatial planning of the guidance device has gone through a long period of improvements. Given the basic necessities required for the element to have a minimum weight for traction system who guide the individual by the particular route. In any case, the weight should not be exacerbated large, as this would make the use of the engine unfeasible. The dimensions of the robot are guided as indicated by the norm NBR 9050:2015, which indicates the anthropometric parameters of human displacement. In Fig. (3), the indications of average values for person using cane and guide dog are presented.
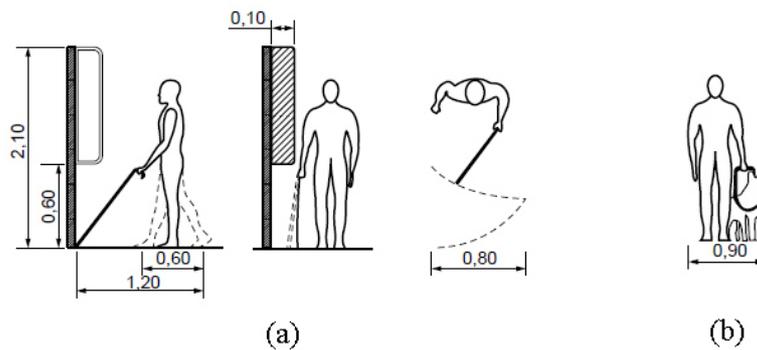
Figure 3. Parameters: (a) Person with cane. (b) Person with guide dog. Source: NBR 9050:2015.

2.1 Prototype Hardware

Aluminum was the material chosen for mechanical design due to its lower weight (compared to steel), to ensure the structural rigidity required in order to not sag or deform, besides the affordable price and availability in the local market. Square aluminum tubes (19x19x0,8 mm), round aluminum rebars (with a diameter of 25 mm) and aluminum plates (1 mm thick) were used.

The control chosen for D.O.G. consisted in combining steering and traction with a single mechanism: the application of independent two-wheel motors. The process occurs similar to moving a treadmill. For a rectilinear motion, the motors rotate their axes at the same speed and direction. The arc-shaped movement is obtained by operating the motors with different rotations, but in the same direction. Finally, the rotation around the axis of the robot is

conquered with the drive of the motors in equal speeds and different directions. From the choice of batteries, reference RB-FM12V7Ah (12VDC).

The DC motor chosen is widely used in Mabuchi model electric drive. This facilitated the structural organization of the mechanical components, since they can be acquired as symmetrical pairs. The operational characteristics, according to datasheet: current of 1,3A and torque of 9,12N.m. Fig. (4) shows the hardware of the guide robot.

Figure 4. Guide robot hardware. Source: Author.

Polarity reversing PWM controllers (also known as H-Bridge) consist of a stand-alone digital system for the control of DC motors. The plate used has the capacity to feed a motor 5A to 15A continuous with peak and power supply between 12VDC to 24VDC.

The communication will initially be made by the user's cell phone, through the Bluetooth system for the IOIO Board (Micro Primary Controller), where it will go through the Iac or Sp protocol, information for the micro controller of the Android board (Secondary Microcontroller), wich is conected to light sensors and presence sensors (Ultrasonic or Infrared) and with a speed controller. In this microcontroller will be all the mathematical functions that will communicate by PWM with a board controlled H-bridge which will start the motors. Such sequence is shown in Fig. (5).
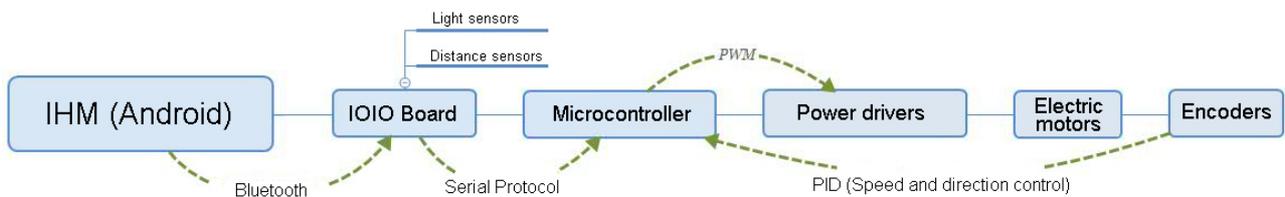

Figure 5. Organization diagram of the communication of the electronic circuit board. Source: Author.

The secondary microcontroller will be responsible for reading the sensors; calculate the mathematical functions to determine the speed of the motors; calculate the algorithms PIDs to control the speed of the motors, besides being reading the encoders and communicating with the IOIO card (indirectly with Android). This board, which is based on an 8-bit AVR, the ATmega2560, in addition to having a processor operating at 16 MHz, it has 256KB Flash memory, 8 KB RAM and 4 KB EEPROM. It can also be highlighted that it contains 4 serial communication channels, 16 analog inputs (10-bit ADC), 54 digital outputs/inputs of which 15 can be used as PWM outputs. The drive system is shown in Fig. (6).
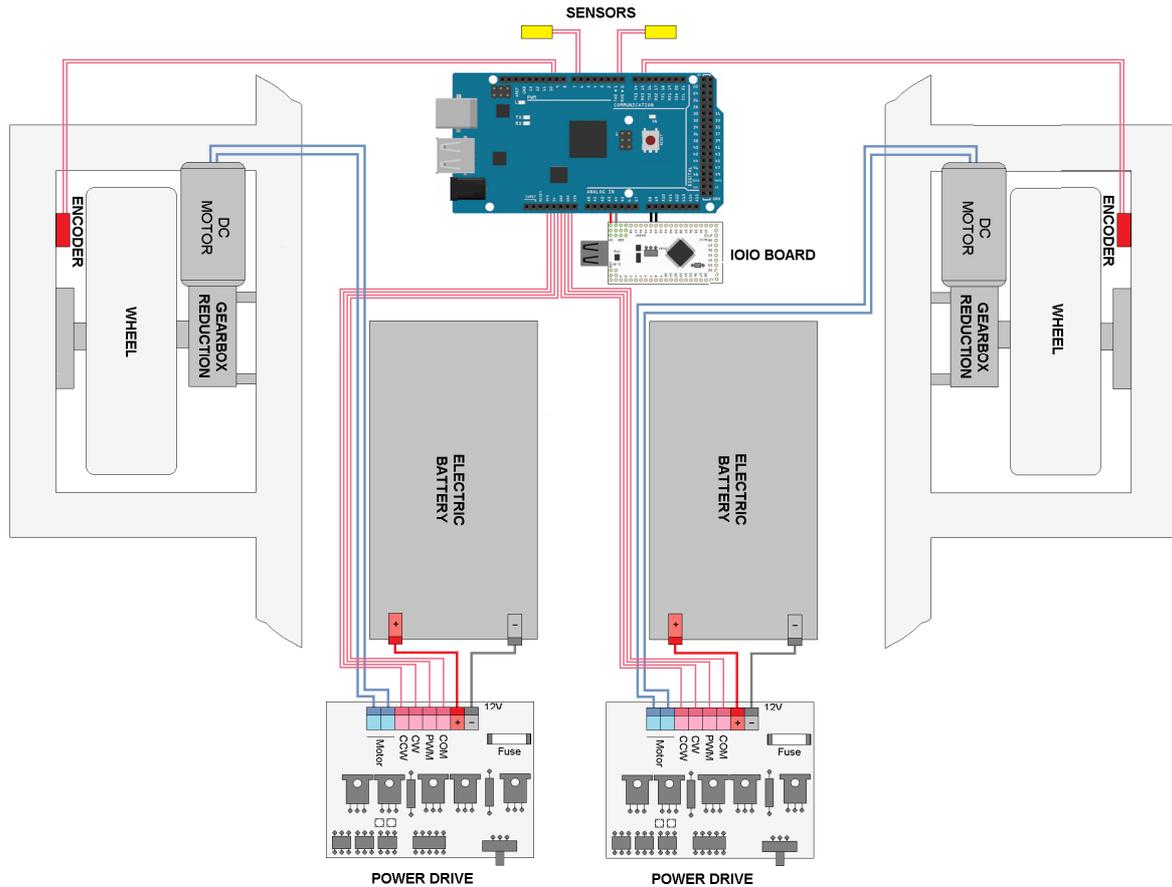
Figure 6. Schematic of D.O.G. Source: Author.

2.2 Guidance System

In the line follower orientation system, light sensors can be used which, by means of a 10-bit analog-to-digital converter (ADC), acquire signals ranging from 0 to 1023 (210). Thus, because of the color reflection property, when the sensor is positioned in the darkest part it will return a minimum value, not necessarily 0, and when it is positioned in the lightest part it will return a maximum value, which is not necessarily 1023. Thus any intermediate color will also return an intermediate value between the minimum and the maximum, and the program can identify luminous intensity indexes, Lux, in percentages, being 0% the minimum (dark) and 100% the maximum (light), identifying luminous differences in a line implanted in the floor of the path traced to the robot. Fixed to the robot, it will be using two central sensors, which will control the motors of traction individually, the sensor 2 for the traction of the left motor and the 3 for the traction of the right motor, as shown in Fig. (7).
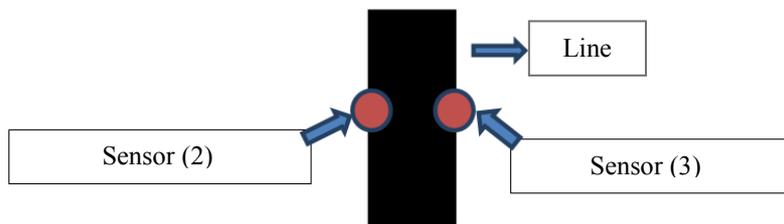

Figure 7. Location of the light signal 2 and 3 on the orientation line. Source: Author.

According to the luminous perception of the sensors, classifying the intensity in percentage form, a linear function can be applied that defines maximum force to the motors when both sensors are in the clearest part. Therefore, the function applied to the motors is shown in Fig. (8).
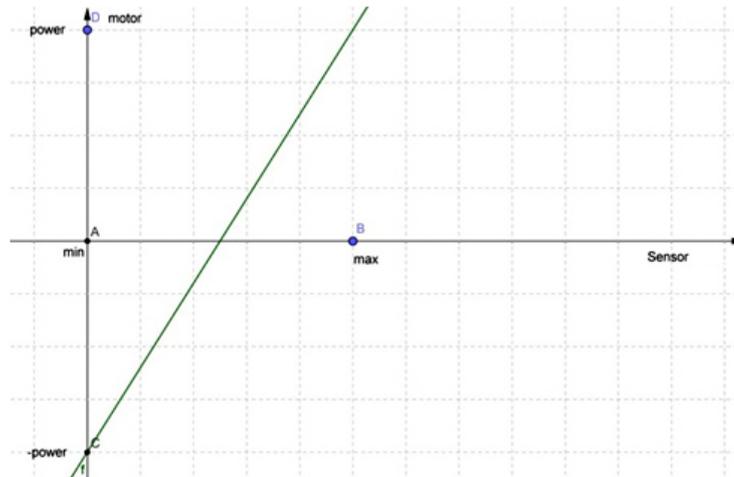
Figure 8. Function applied to control the motors. Source: Author.

To program this function it is necessary to obtain an equation, relating the value of the sensor, the motor force and the minimum and maximum values. The Equation (1) lists all variables necessary for the robot to function; the motor strength, the value of the sensor, the maximum value of force and sensor.

$$y = 2 \times \frac{power(-x + max)}{min - max} + power \qquad (1)$$

The installation of two sensors numbering 1 and 4 will serve for location of cross points of the line path where the robot is. When the sensors pass through a block both sensors will read a low value because they will be in the dark part. When only one sensor notices a dark part, it will indicate that it will be passing through a room. Fig. (9) shows the positioning system and room identifier.
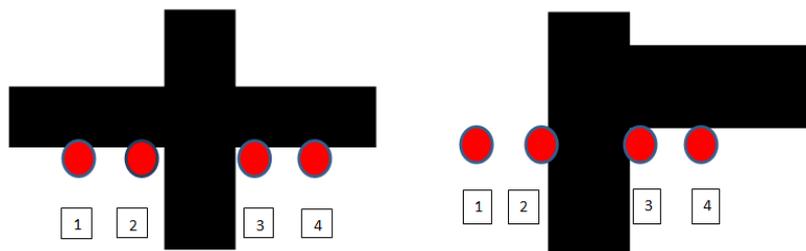

Figure 9. Positioning of sensors at a junction. Source: Author.

3. EXPERIMENTAL RESULTS

3.1 Man-machine interface

The challenge is to establish the concept of the relationship between the user and the equipment. Establishing a communication between the visually impaired and the machine should be simple, easy and habitual to the user, that is, it should be within a technological context already known and usually used by the visually impaired that are the voice system applications of the mobile phone, using Android[®], for example, which will be used in the project for wireless communication through a Bluetooth module. Thus the interface was designed to be a system that works using the user's own cell phone, making it possible to have a better man-machine interface and, consequently, to reduce the final price of the robot. For the use of the system, initially aiming to guide the user only within the establishments of the Federal Institute, it should be informed a routine of settings in the application informing some data of the rooms and corridors that the robot could move. Afterwards the application will be ready for use with the robot. The visually impaired user will be able to initiate a new route informing, by voice command, the destination or canceling the same if he prefers. In order to start these procedures, the most efficient method will be analyzed, which can be done by means of simple, double and / or drags on the cell phone screen or even the button on the headset. In order to realize the "conversation" between the application and the visually impaired, the Application Programming Interface (APIs) "Speech Recognizer" and "Text To Speech" will be used. The first one is used for the user to pass information to the application, where

Google's speech recognition algorithms are applied. The second one is for the application to interact with the user, also through the voice. The application interfaces are shown in Fig. (10).
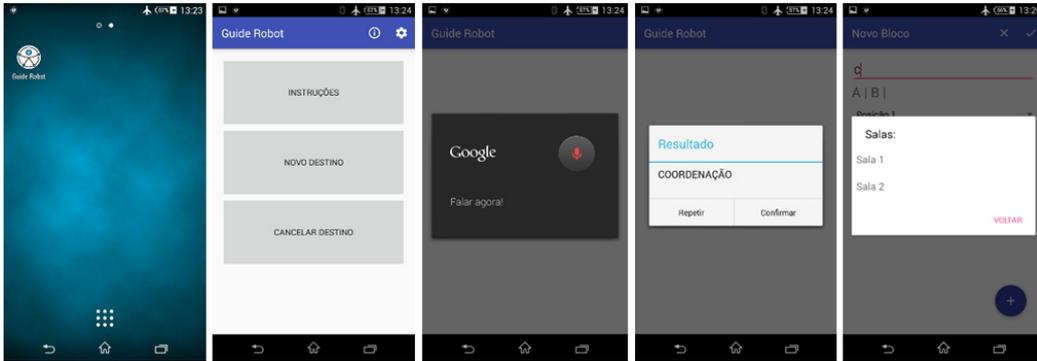

Figure 10. Control application interfaces. Source: Author.

3.2 Speed and Trajectory Controller

One of the great difficulties in the implementation of a PID control is the experimental tuning of proportional, integral and derivative values. The Ziegler-Nichols tuning method was used for the implementation of the DC motor speed controller, and consequently the control of the trajectory.

For this reason, a supervisory program was also created that allowed the output and input visualization through graphs plotted in real time, besides allowing the adjustment of the constants also in real time. This supervisor was programmed in the Java language (Figure 11), and communicates with the microcontroller via USB $\Leftrightarrow$ Serial protocols; for this, the microcontroller must be connected to the computer via USB cable.

The PID controller provided an efficient control of the speed of displacement, maintaining the average of 4 km/h. In addition, the system presented a more than favorable traction force, around 12 Kgf, where it proved satisfactory in obtaining a stimulus to the user for the beginning of its displacement.

Figure (11) shows the interface of the tuner program of the controller, where it is possible to observe the output according to the input. The graph of Fig. (11) shows an input of 300 RPM and an output stabilized at 61 RPM due to the motor reduction box (5:1 reduction). Small variations in velocity can occur due to irregularities in the floor, obstacles or user driving, as can be seen in the graph of Fig. (11) from 10.6 seconds. However, the controller must respond quickly by returning the input speed (cruise speed).

Figure 11. Supervisory for PID control tuning. Source: Author.

The tuning of the controllers that provided the best results determined as gains: $K_P = 0,44$; $K_I = 0,6$ and $K_D = 0,0$.

4. CONCLUSIONS

One of the project's contributions is the applicability and feasibility of implementing the D.O.G. in public institutions as another tool for accessibility to the visually impaired. The line follower can be adapted to the accessibility lines already implanted or being implanted by the federal norms where the anti-slip black rubber floor serves as guide for the robot, adapting only the position of the sensors. In addition, since the communication between the robot is through the user's cell phone, all the campus mapping, as well as the location program of the establishment, can be stored in a cloud and accessible as soon as the user communicates with the robot, facilitating the performance of the robot by memory space.

The speed and trajectory control is obtained by means of a PID controller with support of light sensors for the deviation of obstacles. The PID controllers for each engine were obtained by the Ziegler-Nichols tuning method and presented efficiently in the cruise recovery time.

Among the objectives, one of the most relevant for the project is the interface system through the user's own cell phone. This idea avoided an additional electronic element in the embedded system and, consequently, the increase of the final price of the robot. Besides, the user's familiarity with his equipment made the interface friendlier, since there are some blind people with resistance to technological solutions that can make their life easier.

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6. RESPONSIBILITY NOTICE

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