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Megabots Team: A Team for the Category Sumo Autonomous 3 kg

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Abstract: This paper deals with a method for building a mobile robot in order to transform the material into a practical guide for beginners in the study of mobile robotics. The project is divided into layers that can define the topics related to the areas of knowledge that will be used in carrying out the project. These areas are the mechanics, electronics and computing system. The mobile robot named Fable was developed accordingly to this method. It is composed by two active wheels, each one driven by DC motor with a high torque and a transmission system containing two spur gears. It has three sonars for detection of the opponent and two infrared sensors to detect a line and an Arduino Uno board is used to control all the actions of the robot.

Key words: Layered approach, autonomous robot, systems micro-controlled, war robots.

1. Introduction

Robotics has been involved into human lives from industry domain to daily life applications such as home helper and mechanics, electronics, artificial intelligence, automation and computer sciences, so robotics is helpful to students at different education levels from primary school to university [1, 2]. Learning through designing, building and operating robots can lead to the acquisition of knowledge and skills in high-tech electrical, mechanical and computer engineering areas. These are areas that are in high demand, and can promote the development of systems thinking, problem solving, self-regulation and teamworking skills [3].

Robots have been used for specialized tasks, mainly which are too dangerous for human beings. The robots can be remote-controlled, semiautonomous or autonomous. Autonomous robots act completely on their own in performing tasks, using microcontrollers or computers for controlling the movements of the robot and many different sensors to get the environment data [4]. The design of an autonomous robot is a complex task and the criteria of success are evaluated in terms of its capabilities to make decisions and to act by itself in a reliable and satisfactory manner [5]. The mobile robots follow three branches: land, air and underwater, but the robot construction principle is the same for all three branches.

One of the methods used to develop mobile robots is the method of layers. This method consists of organizing the robot in layers. These are: the mechanical layer which includes the actuator and the structure of the robot; the electronic layer, which includes the entire circuit, communication, and perception. The computation layer is responsible for the autonomous and semi-autonomous control of robot and it is managed through programming. Finally, the integration layer is composed by the three layers unifying them as one [6].

This method was used to build an autonomous robot in order to participate of a robot war competition. The category chosen was sumo robot, in which the mobile robot must push the opponent out of the arena to win the battle. It was necessary to create differential

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traction on the wheels to reach the objective of the competition as well as look for ways to increase the torque of the robot. This way, it could have enough force to push the opponent out of the arena. Furthermore, it was necessary to develop this method using low cost materials due to the limited budget of the project.

The goal of this work is to build a mobile robot that is able to explore environments without human intervention. It must be stand-alone and have the ability to detect obstacles. Additionally, it must be flexible in its mechanical structure and electronics, it is also necessary to show up reliable results and have a low cost.

1.1 Project

The first step that must be followed in the construction of a mobile robot or any project is to fix its objective and determine how it is going to be used. In the case of this project, the objective is to create a mobile robot with the dimensions and maximum weight as established by the rules of competition. It must have a high torque that is capable of detecting the opponent.

Based on this assumption, it is established the most suitable means of locomotion, the type of communication, the way of obtain data from environment and the microcontroller will be used [6].

1.2 The Competition

The robot war competition has taken place in Brazil since 2005. It has five categories of robots: robot soccer, hockey, sumo, line follower, and robot war.

Among these categories, there are several classes that vary according to the weight, size and the ability to be remotely controlled or be autonomous. Among the possible categories, are autonomous, radio controlled and Lego class. Among them, it was chosen the sumo autonomous class, because it is possible to construct it using low cost materials, besides it involves the conception of several areas of knowledge, which is essential for the career formation of the engineer's students. The radio controlled class has a weight limit of 3 kg and maximum dimensions of 20 centimeters wide and 20 centimeters long. There is no height limit. In the Lego class, the weight limit of the robot is up to 1 kg and it just can use LEGO pieces. Among these classes, the Megabots team had participation in the 3 kg autonomous class [7].

1.3 Starting Sumo

The match is played by two teams, each team consisting of one or more members. Only one member of each team may stay in the ring area while the other members should watch the race along with the public. Each team will compete in the dojo (sumo ring) with a built robot according to the category of the competition.

1.4 The Dojo

It is the surface where matches are performed. The dojo has a circular shape with a diameter of 154 cm and a 12.7 cm border line consisting of a steel plate covered with polyurethane [7].

1.5 Project Basic Settings

The project basic settings that are necessary to analyze are the locomotion system, the perception, and the microcontroller that should be used. They were chosen according to the competition rules. The basic definitions of the robot are taken to define the layers. The first one to be defined is the mechanical layer, followed by the electronic layer, and finally the computer integration layer [6].

Fig. 1 Representation of dojo.

Table 1 Basic settings of the fable mobile robot.

Items	Settings
Purpose	Participation in the war of competition in the robot sumo category
Type	Land
Locomotion	Two active wheels with differential traction
Communication	No communication; autonomous
Environment	Circular arena with black surface and white borders
Sensing	Sonar and infrared
Microcontroller	PIC16F628A

Basic settings of the robot are shown in Table 1 and those definitions were used to develop the project.

2. Materials and Methods

2.1 Robot Structure

The chassis of the autonomous robot is basically composed of the blade, the base and the lateral of the robot. The entire chassis is made of aluminum 6061 - T6.

Aluminum 6061-T6 is an aluminum alloy of average strength and it is most frequently used to build structures, ship components, and trucks. It is the most used type of metal to build robots [8].

The representation of the robots chassis is shown in Fig. 2.

2.2 Locomotion System

It is necessary to keep in mind that the sumo robot locomotion system is vital for proper functioning. It was studied, researched and chosen based on the analysis of all types that would fit our reality and our viability. There are a lot of possible options, but we chose solid wheels, mainly because of a more large area of contact between the wheel and the ground allowing a better torque for the robot. There are two specific types of positioning of active wheels: A robot with only two wheels and a robot with four active wheels as shown in Fig. 3.

The robot with two active wheels was chosen because this kind of wheel makes turns much faster and with less expenditure of energy. After deciding to use this type of wheels, it is necessary to keep in mind the need of using support wheels to keep the balance of the robot. There were two supports placed with casters that allow turn faster. The wheels were made from 1020 steel with a 76 millimeter in diameter. The diameter was chosen to generate a high torque since the aim of the competition is to push the opponent out of the ring. The torque generated by the Fable robot is of 3 N.m which corresponds to approximately three and a half times the weight of the robot.

Fig. 2 Sumo robot chassis: 1—Aluminum 6061-T6.

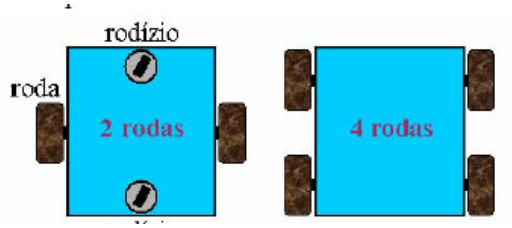

Fig. 3 Types of locomotion (wheels).

2.3 Motors and Transmission

One of the most essential parts for the proper functioning of the robot is the choice of engine. There are several types and models of motors, but the most widely used is the DC (direct current) motor, mainly because they are able to reach high torques. They are easily driven by batteries and have a simple speed control [4].

The transmission system is composed of two gears connected to each DC motor, then it is possible to transmit the power required for the operation and displacement of the robot. The gears are arranged parallel because in this way it has a performance of 90% [9].

The gears were prepared using steel 1045. This type of steel is a low-carbon steel used when greater resistance and hardness are desired. The disadvantage

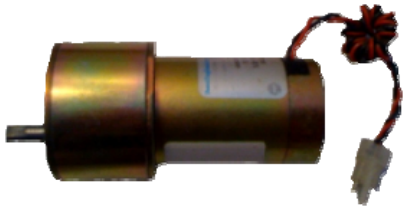

Fig. 4 Motor Pittman.

of this type of steel is the part necessity of a heat treatment after being machining.

The prototype uses DC motors which ensure a high torque and excellent speed and acceleration. The engine chosen was the Pittman. This engine has a maximum torque of 1.5 N.m and the reduction used has a ratio of 1.6:1. It has a final torque of 3 N.m and the maximum speed that the robot can obtain is 54 cm/s and the acceleration is 2 m/s^2.

2.4 Batteries

Batteries are components which greatly limit the autonomy of a mobile robot, in addition to being a significant part of its weight. In most cases, the battery is its major component [8].

The main types of batteries are lead-acid, nickel Cadmus, nickel-metal hydride, alkaline and lithium [8]. We opted for the lithium-ion battery because it has a high-rated capacity valued at 2,300 mAh and it can hold a charge for up to 15 min when in extreme operating conditions. This guarantees continuous operation during the battles as each round lasts at most 3 minutes and there are three rounds of combat.

2.5 Drivers and Sensing

An H bridge is used to allow the DC motor to run forward and backward. It was built with transistors type MOSFET. Using a Darlington configuration, it was possible to produce higher currents to the motors. The transistors used were TIP122 and TIP127 which support up to 8 amps of current.

In Fig. 5, we have the scheme of the H bridge simulated in the Proteus software. This scheme was used to control the DC motors.

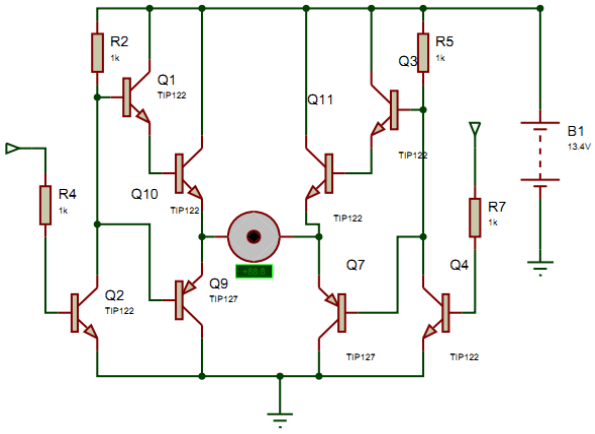

Fig. 5 H bridge using configuration darlington.

In respect to the edge detector, it is the minimum skill the robot should have because the edge detector prevents the robot from exiting the ring by itself.

In this project is used an infrared phototransistor and an LED (light emitting diode) for the edge detecting. As the ring is black and the edge of the ring is white, the edge detector can be used to check the color change. An infrared sensor is used to detect the borders of the arena. In this sensor a 10 k resistor is placed in series to limit current coming though to LED and a capacitor of 10 nF is placed on the phototransistor output to enable the signal pass only to the microcontroller after the capacitor has been loaded. As faster as the discharge occurs, that means the surface is more reflective. In this prototype, two line sensors were used with each sensor located on one side of the robot.

In relation to the opponent detection, three ultrasound sensors located on the sides and back of the robot were used. The sensor used was HY-SRF04 which has one pin to be used as input and one pin as output. The first one is responsible for receiving the signal, referred as echo pin, the other is responsible for sending the signal, referred as trigger pin.

The PIC16F628A is used to control all functions of the robot. It consists of 18 pins, and among those, 16 pins can be configured as input or output. Although this microcontroller only recognizes a digital signal, it could match the needs of the project because the information provided by the sensors was digital. There

were only 5 sensors for information, what means a total of 8 pins needed, and 4 additional pins were needed to control the H bridge, totalizing 12 pins used, what is exactly the number of pins available. It was also used two crystals of 27 pF to generate the necessary frequency to trigger the PIC. The microcontroller circuit is shown in Fig. 6.

The simulated complete circuit in Proteus is shown in Fig. 7. In this simulation, the line sensors are represented by optocouplers Type NPN with a button to interrupt the flow of current to the LED. In respect to the ultrasound sensors, they are represented by the infrared sensor GP2D12 because there is no library in the software that can simulate the ultrasound sensors. This circuit also has two H bridges in the Darlington configuration and each one is responsible to run each one of the DC motors forward and backward. It is powered by a pack of lithium-ion batteries while the microcontroller is powered by an AA-type battery pack to prevent an overload on the microcontroller due to the fact that those batteries used to power the motors have a high-performance.

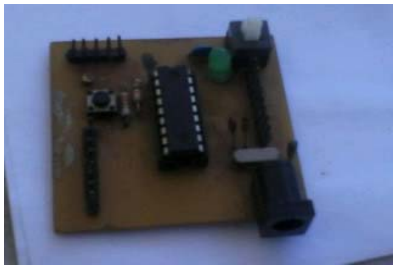

Fig. 6 Microcontroller Board.

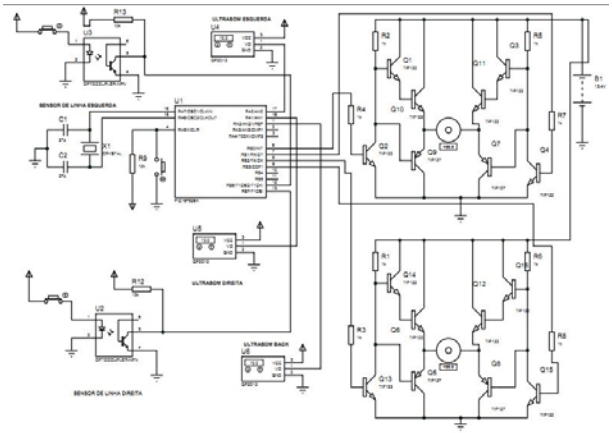

Fig. 7 The entire scheme of the electronic circuit.

3. Programming

The programming of the robot is shown in a simple manner in the flowchart shown in Fig. 8.

4. Results and Discussion

The results obtained from the simulations with the MATLAB and in tests with the prototype are shown in Table 2. This table shows the dimensions of the robot platform, which corresponds to the structure, where is inserted all the electronic and mechanical components necessary for the operation of the robot. The dimensions of the gears and wheels are also shown in this table.

Table 2 Results obtained during simulations.

Variables	Results
Robot's dimensions (cm × cm × cm)	17.5 × 16 × 8
Drive gear (mm)	19.05
Diameter of the gear (mm)	30.48
Diameter of the wheel (mm)	76
Gear reduction ratio	1.6
Nominal torque (N.m)	1.5
Maximum possible torque (N.m)	3
Maximum current (A)	8
Maximum linear speed of the robot (cm/s)	54
Robot's acceleration (m/s^2)	2

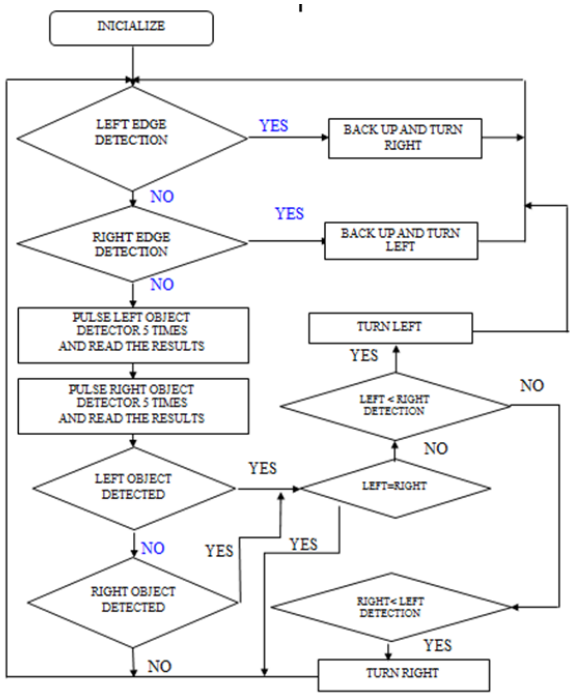

Fig. 8 Block diagram of the autonomous robot.

It is also presented the final torque obtained and the necessary current to be delivered for each engine to generate the required torque. The final torque obtained took into account the weight of the robot itself plus the weight of the opponent with the addition of its normal force. The Fable robot torque was capable of carrying a body with a mass three times higher than itself. This robot participated in the competition of robots called Winter Challenge. It obtained sixth place in the category Autonomous Sumo weighing up to 3 kg.

5. Conclusions

According to the results, it can be observed a good performance of the prototype generated. The robot had a high speed and acceleration and got to obtain an acceptable torque, although ways to increase the normal force should be worked on. One of the possibilities to increase the traction of the robot is to put a magnet roll at its base, so that when it comes into contact with the ring, it will increase the traction of the robot.

In addition to participating of the War Robots challenge, this project brought together as much information as possible, then a student of robotics is now able to start a small project in robotics.

The layer method is expected to be applied in teaching mobile robotics and bring this knowledge to students in public schools, preferably with government support. It is also expected to improve the perception of the robot, and then it can detect the opponent with greater precision and raising the normal force of the robot, as previously discussed.

In order to detect the opponent more precisely, it is planning to use the potential field method to give intelligence for the robot; this way the moves made by the opponent can be predicted in advance.

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