A Robot soccer team as a strategy to develop educational iniciatives

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ABSTRACT

In this paper we described the desing and develop of a robot soccer team such used in Small Size league of RoboCup. The paper shows the use of this team to strengthen the study of mathematics, physics and science by high school students. It is illustrated a relationship between applied design topics of this robots and different subjects studied by teenagers at school. Finally we show that these robots can be used to encourage the study of engineering.

Keywords: Mobile Robotics, education, engineering, artificial vision

1. INTRODUCTION

The robot soccer is currently one of the most interesting research fields, since they embrace a large number of disciplines such as computer vision, intelligence artificial, computer science, mechanical engineering and robotics among others. Also it has become a challenge that appeals to young and old people, not only in research field but also entertainment. Within this approach appears The RoboCup World Championship, which is a research and education initiative. It is based on the attempt to promote intelligent robotics research by providing a standard problem where a wide range of technologies can be integrated and examined, in addition it is used for projects with a educational approach.

RoboCup currently provides to researchers around the world, different types of competitions, it is organized in scopes according with the educational level of participants and topics of researching and developing. These competitions are: RoboCup Soccer, RoboCup Rescue and RoboCup at Home.

RoboCup Soccer: This competition uses soccer such a central research topic, that points to the innovations to be applied to social and industrial problems. The ultimate goal of RoboCup project is to develop a team of fully autonomous humanoid robots that can win a football match versus world champion team of humans on 2050.

RoboCupSoccer is organized by type, size and architecture of the robots participating in different leagues: simulation, Small Size, Middle Size, standard platform and humanoids.

RoboCup at Home: It is a new area of RoboCup, it is focused on real-world applications between humans and autonomous robots. The aim is to promote the development of useful robotic applications that can help humans in their everyday life.

RoboCup rescue: It is one of the main applications of RoboCup technologies, it is related to search and rescue human victims in situations of large-scale disaster. RoboCup Rescue is a project started specifically to promote research in socially significant issues. RoboCup Rescue includes a real robot league and a simulation league.

Our work was initially directed towards construction and operation of a robot soccer team of Small Size League, but after that, we have participated in some demonstration events showing the developing of our team, we began to discover that the robot team has a number of features that help to understand different aspects of robotics, artificial intelligence, artificial vision, physics, mathematics, mechanical and general engineering. Apart from being a device that connects different topics of engineering, it has an attractive for all kinds of people due to soccer is the most popular sport in the world and the idea of seeing robots playing soccer is fascinating for children, adolescents and adults. In this way, robots are being used to teach robotics and encourage the study of mathematics, physics and engineering to high school students.

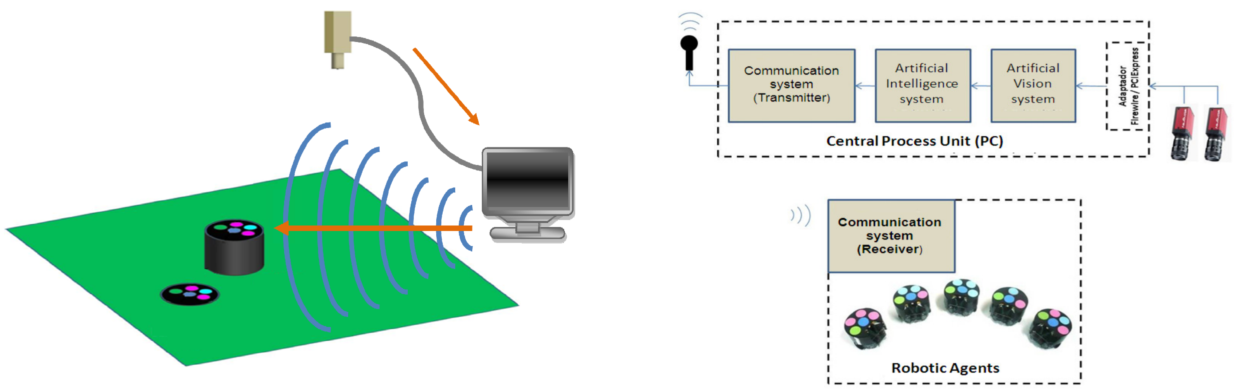
This paper describes a use of a Soccer Robot Team for educational purpose. At second Chapter it is described the operation of Small Size league. Third Chapter provides an explanation of the process to fabricate a robot. In fourth Chapter, it is explained the vision system. Fifth Chapter covers the Intelligence Artificial system and finally, at sixth Chapter is given an explanation of the educational uses of soccer robots to aim students to develop works and research in robotic field. This educational initiative was inspired by previous work “Robot soccer educational courses” (Turic et al., 2010).

2. SMALL SIZE LEAGUE

Small Size Robot soccer is one of categories of the RoboCup. It is focused on the problem of multi-agent intelligence cooperation and the control in a dynamic environment with a hybrid system centralized-distributed.

A game of Small Size Robot Soccer takes place between two teams of six robots each. The robot must fit inside a circle of 18 cm of diameter and its height must not exceed 15 cm. The robots play soccer over a field made of a green carpet of 6.05m long and 4.05m wide with an orange golf ball. Robots can be of two types, with onboard or global vision sensors.

The most common system is global vision, which uses a camera outside and above the field, along with a PC to identify and track the robots that move into the field. The camera is attached to a bar of 4m above the playing surface. The information is sent to the PC outside the field for processing.



(a) **(b)**

Figure 1: (a) Game structure of small size league. (b) General architecture of our team

A PC outside the field is used to follow the referee commands. Usually, this PC is used to make the processing required for coordination and Robots control. Communications are wireless and are used commonly FM commercial transceivers, as shown in fig.1 (a) (Srisabye1 J. et al., 2009).

3. ARCHITECTURE OF OUR TEAM

Our team have a common use architecture, it is similar to others teams of the league, this architecture is a minimum requirement to permit a normal game between two robot soccer teams, this architecture is described below and it is shown in fig.1 (b).

Each robot architecture system plays a key task within the team. The following describes the functions of each system, their design and implementation.

Artificial vision systems, artificial intelligence and the transmitter of the communication system are implemented within the central processing unit, which is a high performance computer (Rodriguez S., Rojas E., 2010).

3.1 ROBOTIC AGENTS

This system is composed by six physical robots, which are structured in modules that perform functions as transport, dribble and kick ball. Besides into the robots there is a reception device of communication system.

3.2 LOCOMOTION

This module has a great importance because it determines the speed and maneuverability of the robot moves. The locomotion system selected for these robots is omnidirectional, because the omnidirectional robots can move linearly and rotate at the same time, thanks to the type of wheel used.

3.3 OMNIDIRECTIONAL WHEELS

The wheels of the robot are made of acrylic; they have a diameter of 7cms, containing 15 small wheels (passive), each small wheel has a rubber coating for more traction, the designed model is shown at Figure 2 (a) and real wheel at Figure 2 (b).

(a) **(b)**

Figure 2: (a) Model of omnidirectional wheel. (b) Omnidirectional wheel developed by our team

It takes at least three omnidirectional wheels to move a robot. Each wheel provides a force in a direction normal to the motor shaft and parallel to the floor. The sum of forces provides the robot movement of translation and rotation.

3.4 KINEMATIC MODEL

The motion of an omnidirectional robot is based on the contribution that each wheel makes to global robot's displacement. The sum of forces caused by each of the wheels resulting in the displacement and final rotation of the robot as shown in Figure 3 and Equation 1

(a) (b)

Figure 3: (a) Omnidirectional Robot in Cartesian Plane. (b) Translation and rotation of omnidirectional robot

$$\begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_3 \end{bmatrix} = \begin{bmatrix} -Cos(\theta_1) & -Sin(\theta_1) & \frac{1}{n} \\ -Cos(\theta_2) & -Sin(\theta_2) & \frac{1}{n} \\ \vdots & \vdots & \vdots \\ -Cos(\theta_n) & -Sin(\theta_n) & \frac{1}{n} \end{bmatrix} \begin{bmatrix} v_X \\ v_Y \\ v_\omega \end{bmatrix} \quad (1)$$

Where Vn is the velocity of each n-wheel, Vx and Vy are the velocities of robot movement on the coordinate axes, rotation velocity is $V\omega$ and, finally θn is angle between wheel and Y-axis

3.5 LOCOMOTION SYSTEM.

For locomotion, the motor used was a Dynamixel AX-12, it was manufactured by Robotis. This motor can be used in continuous mode or servo mode, it has incorporated a speed gearbox, a DC motor and the precision control circuitry with networking functionality, all in one package. The robot has an angular velocity of 60 rpm, but It is attached to a wheel of 4.5 centimeters of diameter so the final linear velocity is 21 cm per second.

Because the locomotion system speed is low, it requires a system of gears, which allows an increase of speed taking into account that the torque should not be too low. The gear system was designed and built on a ratio of 1:5, Figure 4(a) shows the design of the gear system designed in Solid Edge and the real system in Figure 4(b) .

(a) (b)

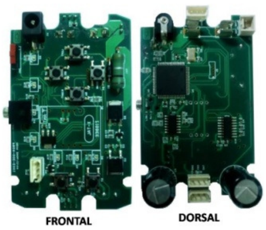
Figure 4: (a) Gear system model. (b) Gear system designed by our team

With the use of these gears it is possible to increase speed as five times to obtain a final speed of 1.9 meters per second.

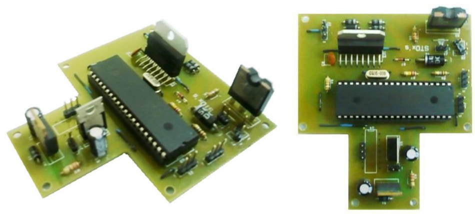
3.6 MOTOR CONTROL MODULE.

This module is responsible for receive information coming from the communication module, it processes and delivers information to each motor of the robot to achieve the movement desired by AI system. The hardware responsible for carrying out this work is based on the development board called CM-5 manufactured by Robotis.

On this board was programed the algorithm responsible for each motors control through kinematic matrix. The matrix is shown in equation 1.



(a)



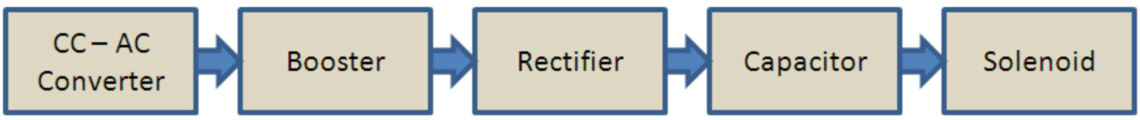
(b)

Figure 5: (a) CM-5 Board (b) Circuit board of the dribbler and kicker system

3.7 THE BALL'S KICKER AND DRIBBLER SYSTEMS.

The kicker system makes possible that the robot can shoot the ball at different speeds while the dribbler system allows the robot to move in any direction keeping ball control (dribbling the ball). For the prototype, these two systems were implemented on the same card and are controlled by PIC16F877 microcontroller.

The ball kicker System activates a solenoid coil to hit the ball at different speeds. The robot is powered by one battery of 9.6 VDC, but to activate the solenoid it is required a voltage of 150 VDC, so it was necessary to design a circuit to raise the battery voltage to activate the solenoid. The kicker system diagram and the solenoid are shown in Figure 6.

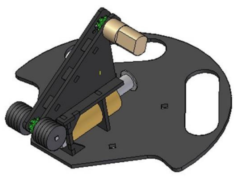


(a)

(b)

Figure 6: (a) diagram of kicker system (b) Solenoid

The ball dribbler system is basic. It was made to activate a DC motor through a IRF830 MOSFET transistor, the MOSFET serves as a switch which is controlled by a PIC16F877A microcontroller. The engine and rubber cylinder are connected by chain system like is shown in Figure 7.

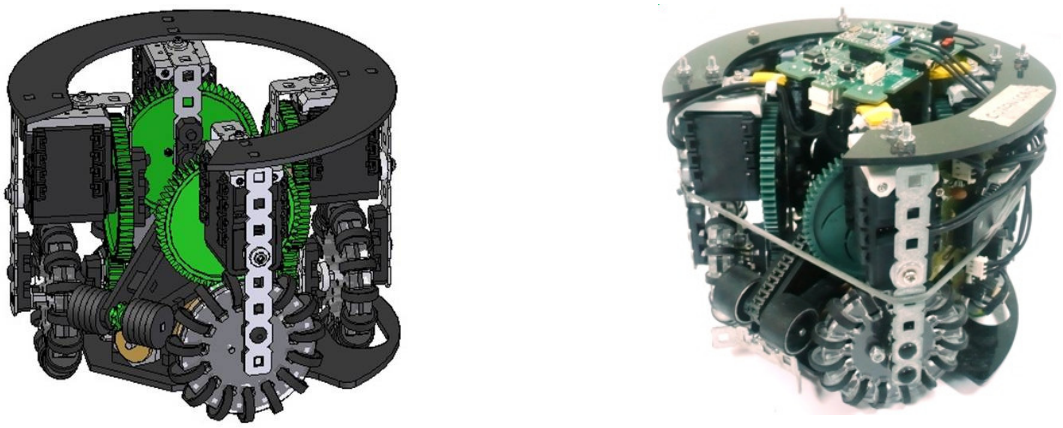


(a)

(b)

Figure 7: (a) Structure model of ball dribbler   (b) Structure designed by our team

The final model of Robot is shown in Figure 8



(a) (b)

Figure 8: (a) Model of Soccer Robot (b) Soccer Robots developed by Us

4. ARTIFICIAL VISION SYSTEM

The main objective of the vision system is to generate a virtual game field model in which are determinate each robot's addresses and positions of our team, opponent robots positions and ball's location.

It uses two video cameras that were connected to a computer where it performs an analysis of images.

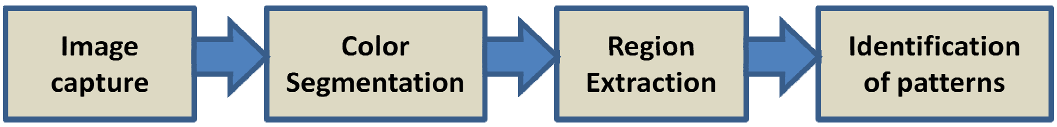


Figure 9: Diagram of Artificial Vision System

The vision system is divided in four steps: image capture, color segmentation, regions extraction and identification of patterns, as shown in Figure 9.

4.1 IMAGE CAPTURE

For this purpose is used a camera located in the upper section over field. This camera captures images of the top of robots in which there are colored markers that identify each team and robots participating in game.

4.2 COLOR SEGMENTATION

The image is normally received in VGA format and is converted to YUV format. The main advantage of YUV model in image processing is the separation of the luminance and color information. The importance of this decoupling is that the image luminance component can be processed without affecting its color component. Based on the color distribution in YUV, applies biumbralización method for the image segmentation processing. The method involves wrapping in parallelepipeds straight zones that are the desired target color within YUV cube. The parallelepipeds are generated straight from an upper and lower threshold for each color layer. For this case the target colors we want get are: orange, yellow, cyan, magenta, green and white (Cheng H., 2001).

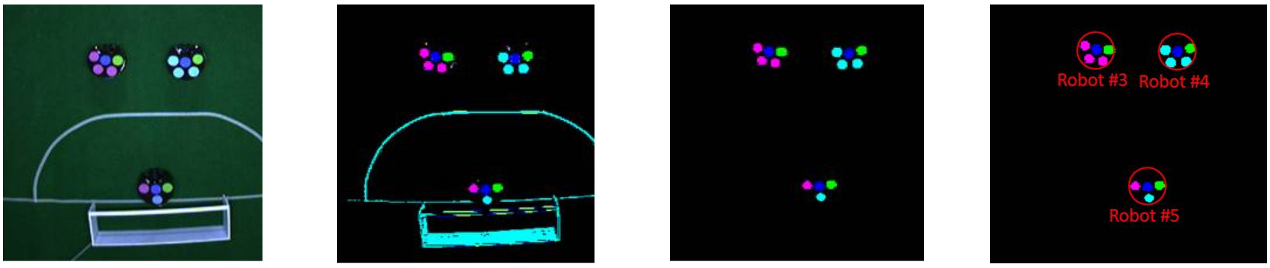
4.3 REGION EXTRACTION.

It uses the segmented image in the previous step, the extraction process is doing in order to distinguish areas of the same color inside the image, that are called regions. This is done by reviewing each of the image pixels, along with its neighbors and its color characteristics. The method used is the growing of regions, this method begins by scanning the image, looking for a pixel that meets the conditions desired color, called a seed. The growing process start looking for the seed neighbors. The neighbors pixels are linked by proximity to the seed pixel. Once it is selected pixels that make up a region, is calculated the gravity center to indicate center of region.

4.4 IDENTIFICATION OF PATTERNS

Depending on the assigned color for team before the game, yellow or blue regions are taken as potential locations of robots. Assuming that our team is identified with blue color, blue regions are taken one at a time and system calculates Euclidean distances to each of the regions of magenta, cyan and yellow. Regions which satisfy the proximity condition (about 9 cm) with the blue region considered, are tagged as marks of an alleged robot. After performing this process for each of the blue regions, there are five groups of regions that contain information of the robots. This will classify the region patterns and ranks each one of robots in field.

The steps involved in process and detection of robots are shown in the figure below



(a) **(b)** **(c)** (d)

Figure 10: (a) Image Capture (b) Color segmentation (c) Region extraction (d) Identification of patterns

5. ARTIFICIAL INTELLIGENT SYSTEM

It´s compound by several process that adjust its game situations and information provided by vision system. In this system has been developed game strategies and other situations like free kicks, penalty shots and indirect kicks that are commands ordered by the Referee Box (Virtual referee provided by SS-League).

The architecture proposed for soccer team is defined as a hierarchical architecture, which is as follows: they have some centralized decision-making processes and other distributed control processes, wherein distributed control information is processed and it can select the actions to be performed. Moreover, these processes are performed by every distributed control agent of system through the behaviour and roles of each of agents.

The processing information begins with data provided by the vision system (virtual stage model) and the Referee Box which are evaluated within a module ready for team's strategy, which dictates the roles (game attitudes) to each one of the robotic agents, depending on the game situation. The block diagram of general architecture is shown in Figure 11.

Since this scheme offers several advantages to the team: quick setup of new strategies, the organization of data lines, the possibility of running a larger number of agents, the possibility of incorporate robots with specific skills and the distribution of processing in each one of agents.

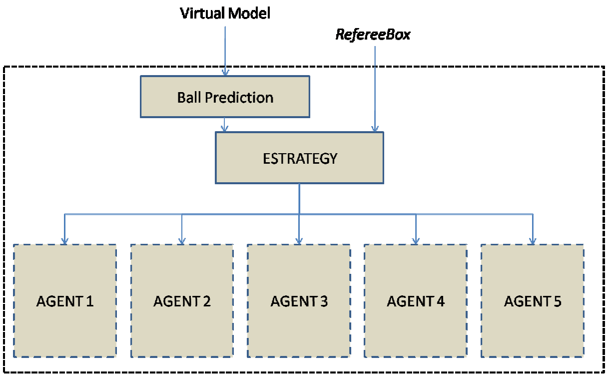


Figure 11: Diagram of artificial Intelligent system

This architecture is compounded by three main parts:

5.1 PREDICTION OF BALL POSITION

This module analyzes data for the ball position. Making decisions when the ball is not on field or there are two or more images of ball on field. The system is responsible for predicting ball position when vision system is unable to see the ball as well as determining game status. This situation depends on the ball proximity to the players and depending on the measure of closeness; system determines whether the computer is in situations of attack, defense or ball is free.

5.2 STRATEGY

This module evaluates different orders of RefereeBox also state of the scene and order role for each agent. Additionally, strategies are based on artificial intelligence as a set of action rules. These rules depend on game status and ball possession. Indeed, the action of a soccer robot depends on the robot position and the distance between robot and the dynamic elements nearby.

5.3 AGENTS

They are entities that performed roles, they have physical and virtual tools that comply with specific tasks, and these tasks also cooperate to achieve ultimate goal.

5.4 COMMUNICATIONS SYSTEM

This system consists of two parts: Emitter, which is a set of hardware devices and simple application to control the serial port and send commands to the robots. Receptors, which are implemented on each robots and are intended to provide information to agents from the artificial intelligence system.

6. EDUCATION

After give you an overview about all different modules that are part of the robot soccer team, there is just one question that remain unanswered. How is possible to establish a relationship between a robot soccer team and the high school education in Colombia?

Although at the beginning, the robot soccer team was developed with the aim to join the RoboCup initiative, at this time these robots are used to encourage high school students to study mathematics, physics, mechanics and computer science. It was made a robotics course with a final objective of construction of soccer Robots, as follows:

Module 1: Tools to construct mechanical platforms. The students learn how to use some basic tools to cut, adjust, assemble, forming and bend some materials. So they use a drill, screwdriver, mini lathe, hammer, pliers, hacksaw, monkey wrench and hand drill among others. At the end of this module, students make the robot mechanical structure.

Module 2: Basic concepts of electricity and electronics. At this level the fundamental concepts of electricity and electronics are teach to students. In addition, it was included the correct use of voltmeter, ammeter and soldering iron. Finally, students weld some components to a PCB.

Module 3: Basic concepts about Robotics Soccer. It is included a full detailed explanation about how the Robots Soccer Team fits to Small Size League, and it shows an overview of systems that are part of robots as the team.

Module 4: Locomotion system. At this module, it is made an analysis about omnidirectional vehicle kinematics and also it is given an explanation about the wheels fabrication process. Finally is given a strong recommendation about the relevance of have a good control of motors.

Module 5: Motors control. Students learn about the electric motors operation and the use of the driver board to control electric motors.

Module 6: Dribbler and Kicker systems. The operation of dribbler system is presented as kicker system. At the end of this module, is proposed an assembly of the control circuit board. It should be made by students.

Module 7: Robots assembly. With the accompaniment of the tutors, students make the full assembly of robot. Then students learn to make some basic tests in order to verify the correct robot operation.

Module 8: Artificial vision system. We teach students the basic concepts related to programming tasks focused on image processing and the general structure of an artificial vision system.

Module 9: Artificial intelligence. At this module, we reinforce some programming concepts and then we teach they behavioral rules and the great importance of have a good behavior in our society. They learn important social skills as good social interaction, cooperation and self control, all those skills are focus on help others.

The development of these modules helps to strengthen some concepts learned at school related to mathematics, physics, science and social behavior. Some of the hand skills, concepts and abilities acquired and reinforced during the development of these modules are presented at Table 1.

Table 1: Hand skills, concepts and abilities acquired

	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module 7	Module 8	Module 9
Mathematical and science concepts									
Algebra				■				■	■
Trigonometry				■				■	■
Calculus				■				■	■
Physics		■		■		■		■	■
Vectors				■		■		■	■
Forces	■			■	■				■
Speed				■	■	■			■
Basics of matrices				■				■	■
Uniformly accelerated motion				■	■		■		■
Voltage and current concepts		■				■	■		
Mechanisms	■			■	■	■			
Hand Skills									
PCB assembly		■				■	■		
Weld		■				■	■		
Voltage and current measurement		■			■	■	■		
Handling mechanical tools	■					■	■		
Programming concepts									
Program structure					■			■	■
Variable declaration					■			■	■
Conditional association					■			■	■
Looping constructs								■	■
Behavior and social aspects									
Behavior			■						■
Decision Making									■
Cooperative behavior			■						■

7. CONCLUSIONS

The use of a robots soccer team to bring in high school students to engineering and science fields is a complex issue. Nevertheless, this process of students learning is strengthened by developing an attractive and funny application that could make easier science learning.

The learning based on projects, helps students to reinforce some concepts acquired at school, since students have a direct application of concepts. Due to the fact that the knowledge acquired at regular classes has a useful benefit to solve real life problems.

When students faced real situations and problems where they can use the mathematics, science and physics theories as well as concepts learned at school they realize that knowledge can be a useful tool in life. It brings a growing interest of science and engineering as well as opens their mind to unlimited social applications of school subjects. The team work developed in this activity has an important impact over the general behavior of students in society; due to students always interact inside real social situations.

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