RoboPET Team Description Paper

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Abstract. The present paper gives an overview about RoboPET project. It explains our ideas, experiences and implementations during the development of the project. RoboPET is composed by a Brazilian group of graduation students of Computer Engineering and Computer Science, which created a low-cost set of robots that is in accord with the rules of F-180 small size RoboCUP category. This paper will describe the most important details on mechanics, electronics and software system of our team.

Keywords: RoboPET, RoboCUP, small size league, F-180 category.

1 Introduction

RoboPET is a project developed in Universidade Federal do Rio Grande do Sul by a team of Computer Science and Computer Engineering students. The project started in 2003, and was reformulated in 2007, when the group defined a new project, based on the original. After two years working in this model, we have been able to develop a functional prototype.

Currently, we have a set of five three-wheeled robots, controlled by electronic boards. These boards have a radio system that makes the hardware-software connection.

The software system is composed by a Vision System and a Decision System. Basically, the Vision System receives images captured by two cameras hanging over the field and sends this information to the Decision System. The Decision System analyses and interprets this data, and chooses the best decisions and tactics to each robot. These decisions are sent to each robot through a radio transmitter installed on the main computer.
The robot specified in this paper (a 3-wheel one, which is the same shown at the qualification video) is only a prototype. In this paper, we will describe our current project and the future improvements we intend to do.

2 Robot Mechanics’

The Mechanics Group is responsible for developing all physical features of the robots. These features are the chassis, the wheels, the motors, and the dribbling/kicking mechanisms. These devices are controlled by the Decision System, and the communication between them is made through radio waves and processed by an electronic board.

The current model of our robot is shown on Figure 1.

![Fig. 1. Sketch of a robot. The dribble system can be seen in front of the three-wheel structure.](image)

2.1 Robot Structure and Dribble Mechanism

The robot is mounted with three omni-directional symmetric wheels. Initially, we made only the dribble mechanism, with a spongy cylinder that holds the ball by rotating, due to the connection with a 9V motor. This mechanism is able to rotate both clockwise and counterclockwise: in one direction, it only catches the ball and keeps its possession; on the other, it pulls the ball away, like a kicker, yet with a very low speed, far from the desired 10 m/s.

The dribble mechanism consists of three gears: one gear on the motor, another in the spongy cylinder axis and a middle gear to connect the others.

Figure 2 shows an isometric view of the robot.
2.2 Robot Calibration

Before any match, the robots are submitted to acceleration and a maximum speed test. These tests calibrate and enumerate our robots.

The calibration is very simple: each robot moves through a line, with maximum speed in two motors, one clockwise and the other counterclockwise, while the third motor stays stopped. By doing this, we are able to calculate the linear acceleration and the maximum speed of each particular robot.

At this point, we also want to calculate the angular acceleration and the speed. These data are calculated by submitting all the motors of each robot to the maximum speed (all motors rotating clockwise or all motors rotating counterclockwise).

The calibration is also used by the Motor Speed Calculator, that will be detailed in Electronics. Basically, it receives vectors generated by the Decision System and converts them into information related to the speed of each motor.

2.3 Next Goals

Even though our robot is able to execute passes and kicks, we consider that we haven’t achieved a competitive performance yet. In order to reach this objective, we need to make some changes, which will be described in this section.

First of all, we need to implement a more efficient kicking device, since ours is just a prototype. Also, we have to develop encoders to our wheels, to rectify the motors performance in real-time. Finally, the dribble mechanism will be improved by replacing the three gear system to a dual gear system, using a more robust motor and a more appropriated dribbler cylinder.
Besides, a 4-wheeled robot is intended to be developed soon. We’re looking for stronger and smaller motors, in order to make a better dribbler bar and a kicking device that uses a solenoid. This change does not modify the calculations made on the calibration step, because all the formulae can be simply extended, thus preserving the calibration process. We already have a sketch for this robot (as shown in Figure 3), and in a couple of months we will have a fully functional 4-wheeled robot.

3 Electronics

The electronic board makes a bridge between the information sent through radio waves and the robot motors. It consists basically of a PIC microcontroller (model 16F877A) that generates a PWM (pulse-width modulation) signal, which is sent to two L293D drivers responsible for controlling the motors. The board also contains the radio module that receives information generated by the Decision and the Vision System.

3.1 Processed Data

The electronic board receives, through radio waves, the speed asserted to each motor. This speed is expressed in a scale from 0 to 35, corresponding to the minimum and the maximum speed of the motors rotating clockwise. There is a signal that can invert the motor, making it rotate counterclockwise. The Motor Speed Calculator receives the vector information generated by the Decision System and converts these vectors to speeds in the scale required by our PIC.
3.2 Communication through Radio

The communication between the main computer and the robots is made using a Low Power UHF Data Transceiver Module made by RadioMetrix (model BiM-418-40) which uses a frequency of 418MHz. Currently, due to cable’s limitations, the data rate is only 9600 bps; thus, considering the 10-bytes protocol developed by our team, each robot receives a maximum of about 20 packages per second. The protocol consists of the strength of each motor and its direction (including the dribble motor), the option of kicking, and some error verification bytes. If another team is using the same frequency for the communication, we also have available a similar DTM made by RadioMetrix (model BiM-433-160), which uses a frequency of 433MHz.

4 Vision

The Computer Vision Group is responsible for analyzing the images received from the cameras above the field, determining the positions of the ten robots (both friends and foes alike) as well as the game ball, and sending these information to the Decision System. The Decision System will determine the next action of each of our robots.

4.1 Vision Software

The vision’s algorithm uses a global view of the field through two overhanging cameras Guppy F-033C IRF, each capturing approximately half of the field.

The Ipl images received from the camera are then converted to RGB format and labeled to gauged RGB values for easier pattern recognition. This labeling process uses multi-threading techniques for maximum optimization. An example of images labeling can be seen on Figure 4.

Fig. 4. Example of image labeling on a static picture.
Afterwards, we segment this labeled image into regions that are necessary for the information gathering. Then, these informations are used to define the robots’ and the ball’s position.
Moreover, we calculate the angle between each robot and an imaginary horizontal line crossing the field. Finally, all the information is sent to the Decision System.

4.2 Next Goals
One of our next steps is to implement a logical probabilistic algorithm to foresee the robots’ and the ball’s position based on their previous position, so that we can achieve the desired speed of our information gathering device. Also we will study the methods utilized by the seasoned teams so that we can be inspired by their work and keep on developing even further our project.

5 Decision System
The Decision System is responsible for processing the information received from the Vision System, which are the ball’s and the robots’ positions, the robots’ abscissa axis based angle and the referee sign. After processing these information, the Decision System sends to the Radio System, that communicate with the Mechanics, the motion vectors and the desired rotation angle of each robot. This vectors and rotation angles are then converted to the four motor forces and sent to the robots.

5.1 Finite State Machine
In order to provide these information, the Decision System uses a finite state machine (FSM), which engine is responsible for considering physics and environment configurations. The referee signs’ determines a high level state that best describes the game situation. This state will define the robot roles, based on its position. Finally, each role estimates the best possible action.
For example, assuming our team is currently under the state A, it proceeds to execute the following steps:
1. Read the low-level information corresponding to the next game cycle;
2. Choose the next state based on the information above and in the current state (in this case, state A);
3. Assign a role to each robot based on their positions relative to the ball, as well as to the foe's position;
4. Send the information associated to each role to the radio system;
5. Go back to step 1.
5.2 Actions

Each robot has a motion vector, an angular rotation and an action, which describes the dribbler behavior. These actions can be: kick, dribble, pass or do nothing.

5.3 Simulator

A simulator, shown in Figure 5, has been developed to aid in the testing and debugging of the Decision System.

![Simulator](image)

Fig. 5. Simulator.

The simulator is able to create the whole game environment and acts as both input (emulating the vision functionality) and output (sending the data to virtual robots). This way, it’s possible to test changes in the software without relying on neither the Radio or Vision systems, nor the real robots themselves.

The physics of the simulator needs lots of improvements, since it’s not really considering all necessary physics law. This modification is already being analyzed by our team, and should be complete by March.

6 During the game

In a simple game, a lot of steps take place repeatedly. The Vision System takes images from the game field, detects all important elements and sends the positioning of these elements to the Decision System.
Then, the Decision System analyses these information and assigns a velocity vector for each robot. Afterwards, the Motor Speed Calculator transforms these vectors into motor speeds, which is the data that the Electronics recognize. The motors’ speeds are sent, through radio waves, to the electronic board, which converts this information into electrical signals that are sent to the real motors.

This process is repeated a few times per second, while the game is on. Figure 6 illustrates this cycle.

**Fig. 6.** During the game, this cycle is repeated a lot of times.