ROBOFEI VERY SMALL TEAM DESCRIPTION 2008

ANDRÉ DE O. SANTOS, GABRIEL FRANCISCHINI, FELIPE ZANATTO, FERNANDO P. TAVARES, JOSÉ A. GURZONI JR, LEONARDO A. FERREIRA, MILTON P. CORTEZ JR, RONALDO K. SATOMI, FLAVIO TONIDANDEL, REINALDO A. C. BIANCHI

Abstract—This article presents the techniques of computational vision, robot control and game strategy used by RoboFEI Robot-Soccer team. The computational vision is based on the Hough Transformation for circles and the opponent detection is based on colors, the robot control has a Proportional-derivative control with Kalman filter, and the strategy is based on game zones actions.

I. INTRODUCTION

SINCE its beginning, the Robot-Soccer challenge has been a motivating platform to research in Artificial Intelligence and autonomous mobile robotics development. It happens because the development of a Robot-Soccer team involves several research topics, like Computer Vision, robot hardware, robot mechanics, control systems and Artificial Intelligence techniques for the strategy of the team.

This paper presents the RoboFEI team 2008 and describes the vision system, strategy, mechanical mounting, path planning and control of the mobile robots used.

II. COMPUTER VISION SYSTEM

In the Mirosot [1] Robot-Soccer league, the robots are distinguished by the colors on their top face labels, which are determined by the rules. The geometric shape of the robot color labels are not stipulated by the rules, just the minimum area of the color, 12.25 cm^2.

The vision system of RoboFEI team detects adversarial robots of any shape by a specific color and the teammates by a circle shape, and the system just consider the color information to identify which are the robots.

In 2008, the base of the vision system, which is described in details by [2], was slightly modified to implement regions of interest (ROIs) to reduce computational overhead and an artificial neural network for color segmentation. The vision system was developed by using techniques like the Canny edge filter [3] and the Hough Transformation [4].

This system has eight steps to process the image. They are: image capture, region separation, background subtraction, color to gray-scale conversion, the Canny edge filter, Hough space generation, determination of the points that have high probability of being circle centers and color classification of objects (robots and ball).

The image capture is done with a capture board or via firewire interface, at 640x480 resolution and 30 frames per second.

The second phase of the system keeps track of the previous positions of the objects, thus allowing the creation of seven regions (six robots and the ball) of reduced dimensions, 80x80 pixels, which will be processed by the subsequent phases of the system. These regions can grow whenever the object is not found, but still represent a great reduction on the computational time spent in the overall vision processing system. All the phases after this will only actuate within these small regions of interest

After the background subtraction, the image is converted to gray-scale and a smoothing and a Canny edge filter are applied, followed to a transformation to the Hough space.

The last portion of the vision system, also modified in relation to previous years, is responsible for detecting the color so the objects can be classified. In this phase, a neural network previously trained using the well known multi-layer back propagation algorithm (MLP) receives the HSV values of the color and outputs the object to what it belongs. The use of the neural network improves significantly the system robustness to luminance variations and eliminates the manual color calibration process. However, to detect adversarial robots, the system uses only color information, ignoring the shape that is placed on the robots label, as described in details in [5], and the idea of color grouping (blob coloring) increases significantly the number of pixels which color must be classified, exposing the limitation of the neural network as a relatively high computational cost solution. To mitigate this potential issue, a lookup table with the contents of the neural network's response to all the combinations in the HSV space (360x100x100 positions) was created.

The performance of the vision system was analyzed in table 1.

TABLE 1 Execution times (all ROIs)

Function	Execution Time
Background extraction	*2ms*
Gray Scale + Canny	*5ms*
Hough Space	*7ms*
Determine Objects	*0.5ms*
Classify Color	*1.5ms*
Total	*16ms*

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Authors are with the Robotics and Artificial Intelligence Laboratory, Centro Universitário da FEI, São Bernardo do Campo, Brazil. (e-mail: flaviot@fei.edu.br, rbianchi@fei.edu.br).

III. Mechanical Mounting

In 2008, a new mechanical mounting is presented, featuring an external reduction box that at same time can increase torque in relation to the former robot and accommodate the bigger size of the shaft encoder mounted version of the Faulhaber 2224 DC motors. The top view of the motor case can be seen in figure 1. The gearbox performs a reduction of rotation of 5 times, using a technique called worm-gear, where a worm part transmits the movement to the gear, as shown in figure 2

The new mounting is designed to have a maximum speed of 1.2 *m/s* and an acceleration of 15m/s^2, while maintaining 8mN/m torque.

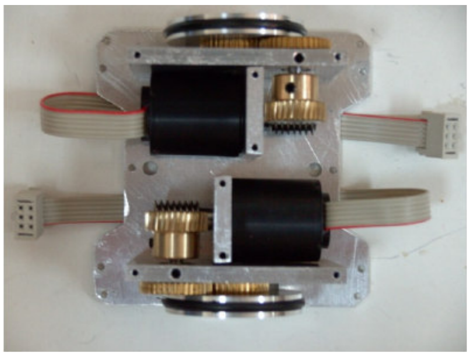


Fig 1. Motor case top view

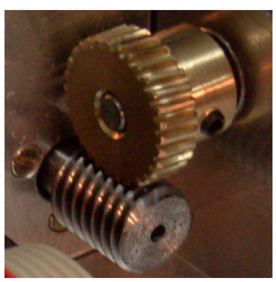


Fig 2. Detail of the gearbox mounting

IV. Control System

To overcome the precision limitation and achieve greater controllability in relation to the control loop based on the vision system, an internal PI control scheme was embedded in the robot, shown in Figure 3. This internal control system, based on odometric sensors, is responsible for ensuring the conversion not only of the linear and angular velocities sent by the upper level control loop, but also to ensure the coordination between wheels is achieved.

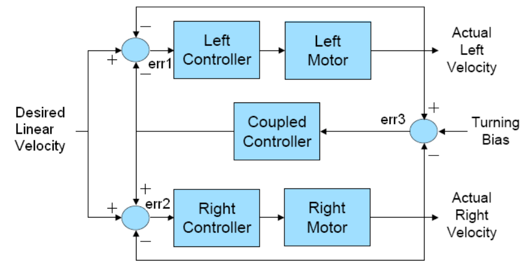


Fig 3 Internal Control loop

The upper level control loop, calculated in the computer software, is based on the differential kinematics, which were used to describe the mathematical model of the robot, as Figure 4 shows.

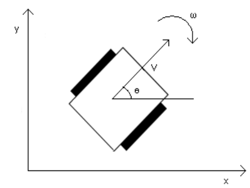


Fig 4 robot kinematics

Where:

- ω is the angular velocity
- v is the linear velocity
- θ is the rotation angle
- (x,y) are the Cartesian coordinates

The equations to control linear and angular velocities are described in details in [7], and they are:

$$v(t) = vc + (kd_p \cdot Se + kd_d \cdot ve)$$
$$w(t) = ka_p \cdot (\theta - \theta_r)$$

The constants of these equations were determined empirically. The tests showed good coordination of movements. The result can be seen in Figure 5.

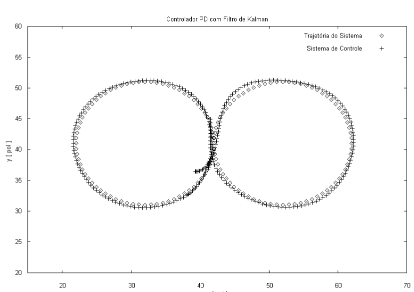


Fig 5 Control System test

The path given to the control system was a set of points forming the shape of an "eight".

V. STRATEGY AND PATH PLANNING

The strategy developed for the team consists in divide the field in seven or eight (middle M can be divided in two) zones, three zones on the attack side, three zones on the defense side and one zone on the middle, as can be seen in Figure 6.

The strategy starts analyzing the zones in which the robots of the team, the adversarial robots and the ball are. This information is passed to a state machine that analyses the possibility for attack and defense.

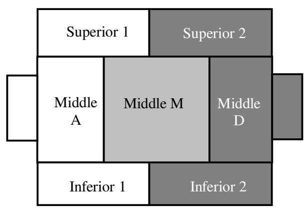


Fig 6 field zones

The states are composed by variables that indicates the zones where the robots are. Depending on the state of these variables, the strategy defines the action for each robot. For example, to intercept the ball, the nearest and relative to *x* coordinate behind the ball robot is chosen.

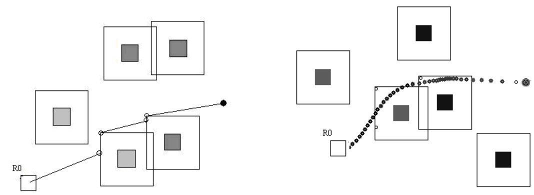
Depending on the zone the robot is, an action has a weight greater than the others. In the zone Middle A, for example, a "Kick to Goal" action has priority.

There are few actions that can be performed that, when performed in sequence, can show complex movements. The actions are: kick to goal, ball interception (the same as opponent obstruction), run with ball, pass (kick ball to a specific zone), stop and spinning (to kick the ball in corners or to retrieve ball from opponent).

To move the robots through the field, is applied a technique known as Piecewise Bezier [6] to trace the path of each robot of the team. The first path traced is composed just by line segments, as can be seen in Figure 7(a). Each object that intersects a line segment has a potential field that makes the algorithm to retrace the line segment to avoid that obstacle.

Given the line segments, Bezier is used to smooth the path and the points are passed to the control system. Figure 7(b) shows the smooth path generated by Bezier algorithm.

The control of the path is done based on the estimated time for the robot to follow the path. The next point that the robot must follow in the next 30 milliseconds is determined and it's applied to the control system. This time is fixed in 30 milliseconds because the system captures 30 images per second. So, the vision system, strategy and control must spend a maximum of 30 milliseconds per iteration. If it won't happen, image frames will be lost.



(a) *(b)*

Fig 7 Path planning using Piecewise Bezier

VI. CONCLUSION

The new RoboFEI team, if compared to the old ones, has a vision system that handles better with noise, luminosity variation and perform faster.

The strategy has more actions to choose for the robots, given the position and rotation angle by the vision system more accurately than the old system. Now the system has an obstacle avoidance and path planning algorithm for the better move of the robots.

The control system is capable to control the robots accurately, estimating the future position and rotation angle and calculating the velocities for the motors.

The next steps are testing exhaustively the new system and find the lacks to be improved.

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