FOOTBALLER ROBOT TEAM DESCRIPTION

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ABSTRACT
Autonomous mobile robots are ever increasing their number of different applications, even in ludic application or in sports. In the last few years, several competitions of football have been organised with lots of teams participating. This paper describes an Autonomous Mobile Robot which plays football and it was developed at the Industrial Electronics Engineering department of the University of Minho in Guimarães, Portugal. Each team is free to solve on his own way all the different electronics, sensory systems, playing algorithms, etc. as far as they cope with the rules imposed by the organisation. Instead of using several different sensors increasing electronics complexity, it was decided to use only one major sensor namely a vision system with the use of a colour camera. All the image processing algorithms were developed from scratch and are hereby described. This vision system uses an innovative approach. In order to see the whole field, a convex mirror was placed on the top of the robot looking downwards with the video camera looking upwards towards the mirror. This way, the robot can see both goals, the ball and other robots, almost all the time, as well as having a top view.

Keywords: Mobile Robotics, Autonomous Robotics, Image Processing, Football Robot Contest

1. INTRODUCTION
A robot was built to participate in an international competition of robotic football, namely the "Festival International des Sciences et Technologies" held in France.
These type of competitions are getting more and more frequent as well as more competitive as more universities are getting involved. New and innovative ideas are being raised by different teams from all over the world, not only on mechanics means but also on electronics, computer science, image processing, etc. Although this type of robotics application seems to be only ludic, some of the techniques developed can then be used in industry for real applications.
In this team a group of people was gathered together from different field: electronics, computer science and mechanics in order to achieve the best possible solution.
This article describes the robots as they were implemented for the previous competition and the improvements made specially for the RoboCup99 to be held in Stockholm.

2. ROBOT DESCRIPTION
All the robots of the team are equal. This means they have exactly the same hardware and the same software. Therefore, only one robot will be mentioned in the text.

2.1 HARDWARE
Presently the robot hardware architecture consists mainly in a vision system, an onboard computer and an electronic module to interface the computer with the two motors, sensors and actuators.
The robot is based in a wood platform with two propelling wheels (and two support points) so the robot direction is obtained by differential control of the two DC motors.

The Vision System consists of a CCD video camera, a convex mirror and an ordinary frame-grabber. The association of the convex mirror with the camera provides 360º of visibility to the robot as well as a top view of the field.
The “Brain“ of the system is an ordinary PC equipped with a 200 MHz MMX Pentium processor. The computer controls literally everything from image acquisition to motor speed. The two DC motors are driven by Pulse Width Modulation (PWM) generated at the computer. Since the two wheels are equipped with optical speed encoders, the computer can make an efficient speed and position control, which is very important to maintain a stable direction and to allow dead-reckoning techniques.
The energy for the system comes from two 7Ah Lead-Acid batteries. One of them feeds the DC motors while the other is dedicated to the computer.

2.2 SOFTWARE

The Control Software that drives the robot is organised in a 3 layered hierarchy, namely: High Level State Machine, Dynamical Direction Control and the low level Motor Speed Control.

The State Machine GRAFCET based algorithm takes care of the robot and game status and provides the major directives to the behaviour of the robot. The Dynamical Direction Controller is responsible for keeping the robot in the correct and stable trajectory towards the ball, the goal area or opposite team robots. The velocity control consists of a classical Integral-Proportional algorithm.

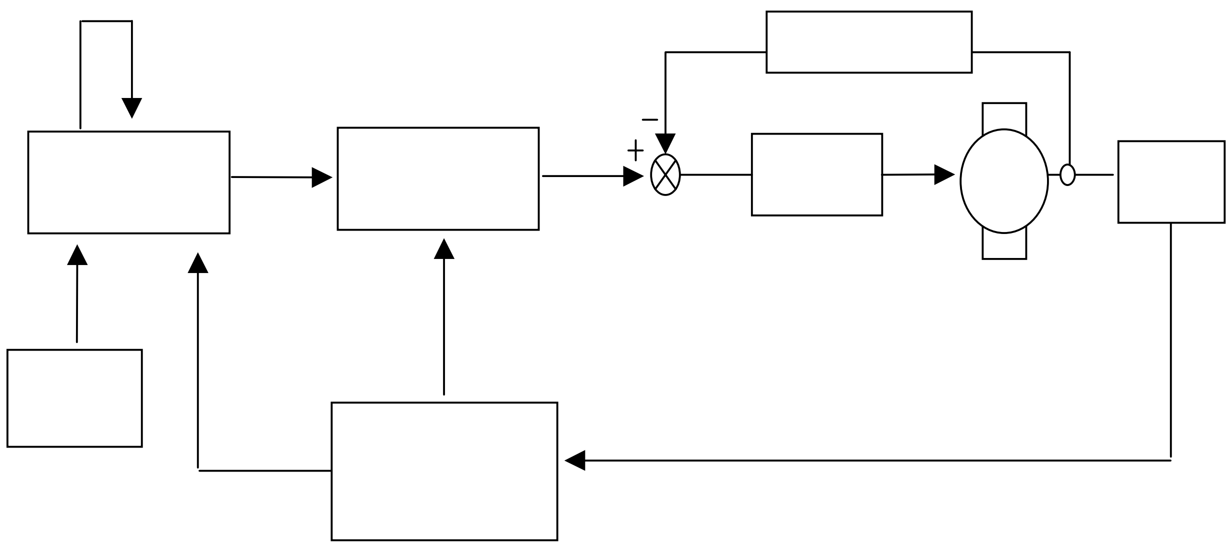

Figure 1: System description chart

These control algorithms use input provided by some support software modules such as the Image Processing Unit or the Velocity Encoders driver and produce output to other support software such as the PWM Generator Unit.

The other robot output comes from the PWM generator that controls the energy provided to each motor. This modulator receives the speed requirements from the high-level control modules and drives the DC motors directly through a bi-directional Power Bridge.

2.3 IMAGE PROCESSING

Despite the Image Processing could be considered software, due to its importance in the robot it was decided to have a section specifically dedicated to it. This is responsible for keeping track of the ball position in the field, to locate the goal area and opposite team robots. The approach used is based on colour segmentation techniques, so the robot identifies the ball and the two goal areas using different colours on each of these entities. An acquired position in the image can be translated in a field physical position very easily thanks to the panoramic view provided by the convex mirror. Since most of the core routines were implemented in Assembly Language the robot is able of processing more than 30 frames per second.

The convex mirror used enables the robot to have a wider and better vision in every direction and from the top. The convex mirror conveys the surrounding scenery to the camera. This increased vision field enables the robot to locate the ball, as further as 8 metres away, although this value is dependent on the distance between the mirror and the camera. The 360 degrees vision helps to control the ball without losing it from sight or to detect the presence of opponent robots even at the back side. The vision from the top helps to locate the ball, even if this is behind other robots. This way, time is not wasted to search the ball. This technique enables the robot to see the ball and the goals on the same image. Next figure describes the position of the mirror and the camera.

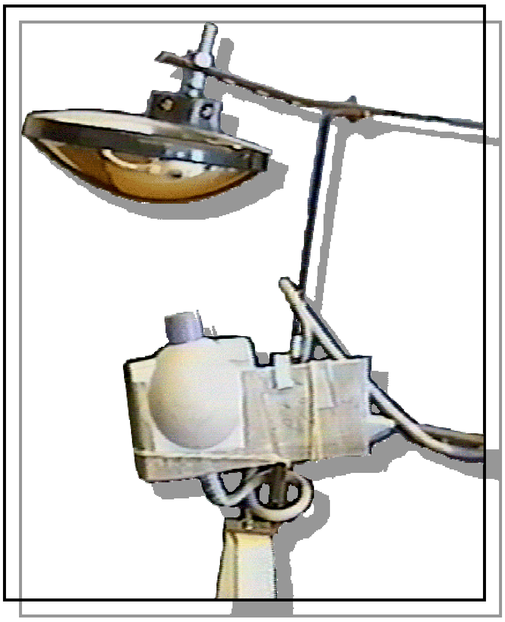

Figure 2: Mirror and Camera Support (side view)

Since the image processing detects the ball and goals by its colour, distortion caused by the mirror can be ignored. Advantage can be taken from this distortion because when an object is closer, its size is increased by the mirror, being represented on the image with more *pixels* and therefore the detection becomes more reliable with higher precision.
With the use of the convex mirror, the robot does not need to run all over the field, looking for the ball or the goal. Therefore, the robot moves towards its targets, saving energy and time.

The next figure shows a typical image taken from the video camera (please, ignore all the other objects on the image). It is visible that the image is slightly curved due to the shape of the mirror, but as it can be seen no algorithm is necessary to correct the image. This image is perfectly workable.

Figure 3: Robot Vision

3.0 IMPROVEMENTS DEVELOPED FOR ROBOCUP99

To participate on the RoboCup99, a new approach with some innovations is being developed which consists of using genetic algorithms. These innovations concern mainly the highest levels of the control hierarchy, namely the State Machine Algorithm and the Dynamical Trajectory Controller. The idea is to replace the rigid behaviour imposed by the State Machine Algorithm and to implement a more natural, dynamic and effective behaviour that is much closer to a human soccer player attitude on the field than the old approach. These new ideas should provide a simple and natural method to program different personalities to the robots and to test different co-operation strategies for the team.

3.1 BEHAVIOURS

Six possible and independent behaviours that the robot can assume at any time, were chosen. Even though all these behaviours are latent in the robot's "mind/spirit", some of them emerge and disappear dynamically in response to the environment evolution, while others stay active all the time. Moreover, some of these directives are concurrent, while others are complementary. The robots should be distributed through the play field such that each element should have a home position in the arena. They are supposed to co-operate by passing the ball anytime a robot enters another one's covering area.

Behaviour	**When**
Acquire the positions of: ball, goal & home	Always
Avoid obstacles	Always
Go towards the ball	The ball is alone or with an adversary
Go towards the goal area	I possess the ball
Go towards a colleague	I possess the ball and I'm far from home
Go home	I'm far from home and there's nothing to be done

These behaviours are excited or inhibited in response to several parameters regarding the surrounding environment or game evolution. Some of these parameters contribute to the emergency of certain behaviour while discouraging others. Time is an important parameter which is implicit, for instance, in the confidence of the ball's position knowledge.

Behaviour	**Related Parameters**	**Type**
Go towards the ball	Confidence of ball's position knowledge Distance from Home	↑ ↓
Go towards the goal area	Control of the ball Confidence of goal's area position knowledge	↑ ↑
Avoid obstacle	Proximity to the obstacle	↑
Go towards a colleague	Control of the ball Distance from Home Confidence of colleague's position knowledge	↑ ↑ ↑
Go home	Distance from Home Confidence of ball's position knowledge	↑ ↓
Turn head in recognition	Confidence of ball's position knowledge Confidence of Home position knowledge Confidence of goal's area position knowledge	↓ ↓ ↓

Legend: ↑ excitatory parameter
↓ Inhibitory parameter

Associated to each of these parameters and for all possible behaviours there is a coefficient of importance that must be calibrated so that a successful action and interaction of the players can be achieved.
The calibration of so many coefficients has leaded us to the development of simulation tools where a dynamic and self-calibrating algorithm can fine-tune this great number of coefficients. These kind of complex problems fit very nicely in the field of Genetic Algorithms.

This new technique is being developed from scratch and is almost in testing phase to prove its feasibility.

4.0 CONCLUSIONS

The participation in the autonomous mobile robot football contest (prior to RoboCup99) was very successful. No other teams used 360 degrees vision with a single camera and therefore they could not see all the object at all the time. While they were moving around to capture all the information they needed, this robot team was moving towards the goal.
The convex mirror gives several advantages like 360 degrees vision, vision from the top, increased field of view area, more concentration of pixels in the objects near (allowing higher precision in the calculations), and all this is achieved with only one camera, reducing though weight and saving energy for other tasks.
The image processing software written is in Assembly language in order to increase processing speed. This proved to be a big advantage since around about 50 frames per second were obtained. The rest of the program is written in C language.
The use of genetic algorithms improves greatly the performance of the robot team. It is very important to set up the correct parameters otherwise the team will not work properly New rules

could be implemented although with the ones described in this paper the performance is perfectly acceptable.

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