F. Ribeiro, *Member, IEEE,* I. Moutinho, P. Silva,
P. Braga, N. Pereira

MOBILE ROBOT CONSTRUCTION FOR EDUTAINMENT APPLICATION

ABSTRACT

As time goes on, there are more and more robotics applications. The limit is almost the imagination of each person. A great deal of industrial work can yet be done by robots and new ideas are blossoming. The entertainment industry is arriving and there are already many ideas as well as real robots on the field. It is important to point out that the entertainment applications not just entertain people as it also brings new research which will then be used in industrial work applications. This paper describes a team of robot football players which compete in a worldwide scientific challenge – the RoboCup.

I. INTRODUCTION

Nowadays robots can do many tasks which were unthinkable a few years ago. Not just important tasks like industrial work, demining or rescuing but also entertainment like dancing, chess or football playing.

RoboCup is an international scientific joint challenge to promote Artificial Intelligence, robotics, and related field. The main objective is to foster intelligent robotics research by providing a standard problem as simple as the football game where wide range of technologies can be integrated and examined. The ultimate goal of the RoboCup project is "By 2050, develop a team of fully autonomous humanoid robots that can win against the human world champion team in soccer" [1]. This challenge is held annually, started in 1997 in Nagoya Japan and this year of 2004 is held in Lisbon, Portugal. During these years many teams have participated had created many robots with specially built devices to control the ball, to kick the ball, to dribble, etc. MINHO team is one of them [2], [3], [4]. A study was also carried out in order to evaluate other team's solutions and is described in [5]. This team has since 1998 developed several new features, from which it is important to point out the strong kicker, the ball controller device as well as a hyperbolic/conic mirror.

To the public in general the final objective is to play and win football games, but in order for a robot team to actually perform a soccer game, various technologies must be incorporated including: design principles of autonomous agents, multi-agent collaboration, strategy acquisition, real-time reasoning, robotics, and sensor-fusion. RoboCup is a task for a team of multiple fast-moving robots under a dynamic environment. This paper describes these robots design and construction and focus on the game strategy.

II. ROBOT BODY

The RoboCup football game rules are based on the FIFA rules but with some amendments in order for the robots to cope with the game. The field is about 12x8 meters of green carpet with the traditional white lines. Each goal is 2 meters wide but 1 meter height and 0,5 meters deep, and they are coloured; one completely yellow and the other completely blue. The ball is RED FIFA size 5. All robots must be mostly black coloured and each robot team uses a mark to distinguish the team mates; one team uses cyan and the other uses magenta. Each team can play with four robots and can have substitutions. The robots should not collide (there exists yellow and red cards which can be given by the human referee) and they must score as many goal as possible during the 10+10 minutes games.

There are also strict rules for these robots to participate on the football competition specially what concerns size, weight and ball controlling devices. The rules can be read in [6].

Many teams buy robots off the shelf and then only adapt some sensors and devices to control de ball or to kick, but MINHO team built the robot from scratch. All the mechanics, electronics and software is made in the laboratory. First it was designed in a CAD program in order to check its size, parts fitting, weight, general aspect, etc.

Figure 1 · CAD drawing and real robot.

Then a prototype was built in order to check if everything would work out and only then the other 3 robots were built.

This robots has 5 main sections: The bottom section where the three driving motors, wheels and encoders are attached to; above that there is the motor electronic boards, the four batteries and the kicker; next section has mounted the kicker electronic board and the ball handler; after there is the computer motherboard and finally and at the highest physical position there is the vision head.

Three driving wheels are used because it brings many advantages (a comparison between two, three and four driving wheels, as well as the kinematics description of this solution can be read in [7]). With three driving wheels with 120 degrees between them the robots have increased manoeuvrability, run faster towards the ball, and the motors barely run at their maximum speed. The motors chosen were the Crouzet DC geared motor with brushes, with 5Nm at 33 Watts. In order to use this three wheels solution, special omni-wheels have to be used. These wheels contain small cylinders which allow a movement in any direction. Figure 2 shows the bottom section of the robot.

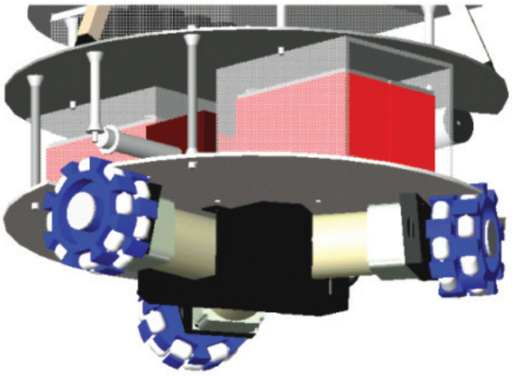

Figure 2 · Driving section – wheels and motors.

The section above contains four lead acid batteries 12V 7Ah, three used on the motors and one on the computer, and the kicker which consists of an electromagnetic coil with an iron core. At the other end, a cylindrical shape nylon piece is attached to the metallic core and pushes the ball forward, when current passes through the coil. It charges for another kick in about 3 seconds. If a kick is needed during charging time, that is possible although not with the maximum power.
This section also contains the motor electronic boards which control the motors and limit their current when necessary. These boards were also developed in our electronics department by the team members.

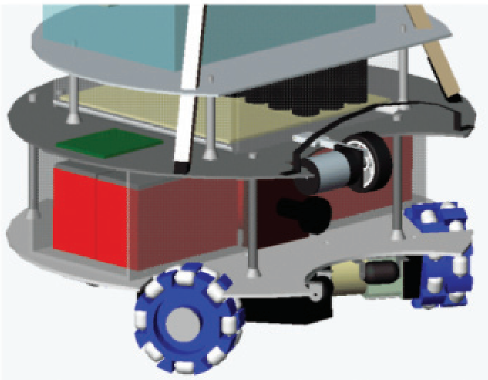

Figure 3 · Second section – Batteries and kicker.

The section above contains the kicker electronics board which is described in [8], and the ball handler. The ball handler consists of a rotating rubber wheel from modelling cars which when in contact with the ball rotates the other way round. This movement makes the ball spin on the opposite direction of robot direction keeping the ball by the robot's front, and making it easier to move it and kick it.
The computer consists of a low consumption motherboard VIA EPIA M + C3 running at 933 MHz is used, with 256 Mbytes of P266 memory and a 2.5" IDE Flash Drive with 256 Mbytes. This motherboard has a VGA board embedded, supports USB 2.0, it has 1 parallel port (from where the outputs are sent to

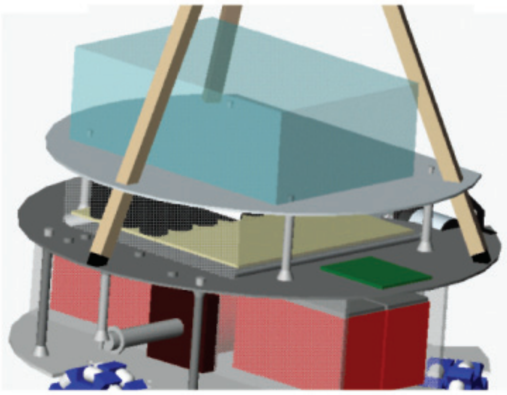

Figure 4 · Kicker electronics board and Computer.

the motor controllers), 1 serial port and a PCI slot. A two PCI raiser is used in order to connect the two boards (wireless Network board and the frame grabber). The wireless network board is standard IEEE 802.11b and is used to communicate between all the robots and also to the computer outside the field. The outside computer is only used to start the game remotely and to receive show the data that is passing by between the robots in order to debug the game. The frame grabber is a Bt848 chip based and a composite video in signal is used.

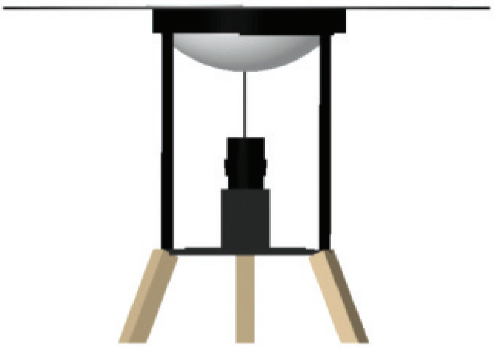

Figure 5 · Vision head.

The vision head is hold by a metallic tripod attached to the platform below and consists of a TC-5173 video camera facing upwards onto a hyperbolic/conic mirror. With this technique the camera grabs an image of the whole surrounding robot. A 360 degrees image is achieved allowing the robot to have always visible the ball, the goals and obstacles at the same time and on the same image.
The camera is electrically fed by the 12V from the motherboard power supply.
An example of an image grabbed on a football field is shown in Figure 6.
A graphical representation of the main hardware is shown in Figure 7.

III. ROBOT BRAIN

The robot's computer runs Linux Slackware 8.1 as operating system and all the software is written in C language.
Three levels of software were created:

1) The first layer consists of a HAL (Hardware Abstraction Layer). All the routines that control hardware are at this bottom layer and the programmer just needs to know the correct parameters to send to the hardware. These routines are completely independent to the rest of the software.
2) The second layer takes care of the video grabbing in real time, colour

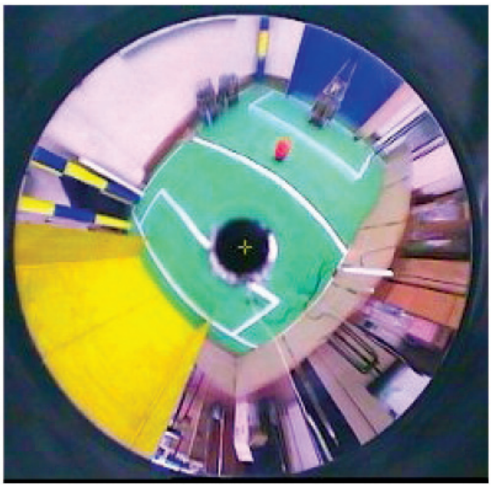

Figure 6 · Image grabbed by the vision head.

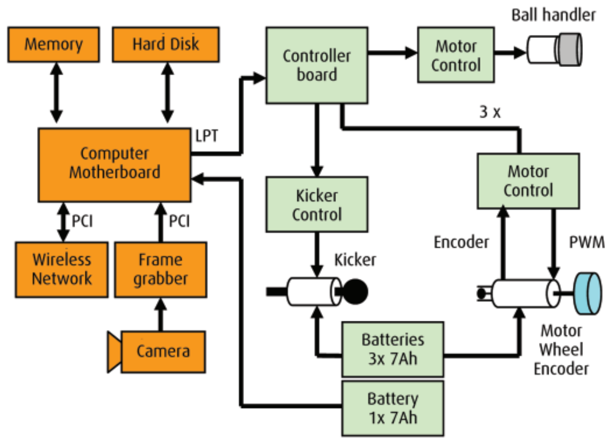

Figure 7 · Robot's main Hardware.

segmentation in real time and virtual sensors. The video grabbing routines are extremely optimized and after the whole processing around about 15 frames per second are achieved. The colour segmentation uses an RGB cube technique and is not described on this paper.

3) The third level consists of the main game program. It takes care of the game perception, playing strategy, behaviour control and communication between robots. Although, the robots do not carry a computer screen, this program has a kind of interface but just used for debug purposes.

The game program is exactly the same in all robots, and the behaviour of each robot is dependent on the surrounding environment conditions on the field and on the number of robot team mates. For example, if the goal keeper has to go out of the field, another robot player will become goal keeper.

IV. STRATEGY

The main strategy consists of 4 players: One goal keeper which is always on the goal, one defender which stands on the field like a goal keeper but 3 meters away from the goal, one attacker which is the nearest robot to the ball and it follows the ball, dribbles and kicks to the goal if the was is free. The fourth behaviour is a striker. This robot positions itself in a clear way to the attacker and to the opponent goal. This behaviour permits itself to receive the ball and to kick to the goal.

Figure 8 shows the behaviour order dependant on the number of players actually on the field. Should the defender be out the striker behaviour will disappear. With two players only on the field, the attacker will also disappear, and so on. The last one to disappear is the goalkeeper as expected.
This cooperation behaviour is possible only since the robots can communicate between them. The wireless network boards used are 802.11b standard and the communication speed is 11Mbits.

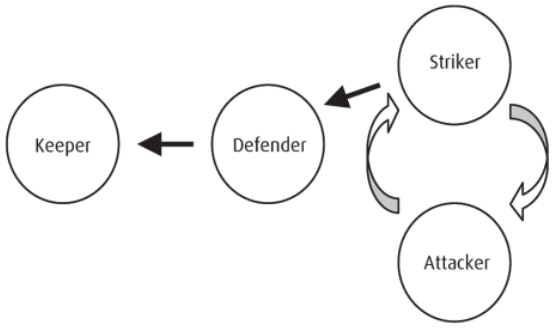

Figure 8 · Robot's behaviour.

The network functional module uses the parallel programming technology of threads. There is a common area of memory in all robot players to which all robots send their game variables. This way all robots know exactly the team mates behaviour conditions. This communication is held once every second and consists of around about 120 bytes of data. Some of the information sent is a signature of each robot, its name, behaviour and state, position within the field, position of the ball and goals, the obstacles position around the robot, velocity and direction of movement, batteries voltage, the kicker status, etc.

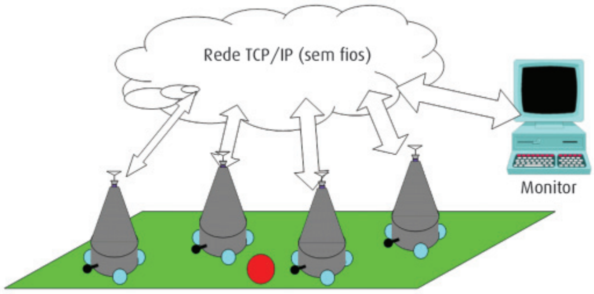

Figure 9 · Wireless Network.

V. ROBOTS BEHAVIOURS

In order to have good game performance and quality visible to the audience, the robots must behave as close as possible to the human type of football playing. That is not easily achieved. This section will be dedicated to a brief description of this team robot's behaviours.

A. Goal Keeper and Defender

The goal keeper positions itself in the middle of the goal while the ball is far away. When the ball approaches it moves towards the ball side without leaving the goal. When the ball is very near the goal it moves forward to kick the ball and goes back to the stand by position. Basically it has two different states: Protect the goal and attack the ball.
The Defender has exactly the same behaviour but its position is 3 meters away from the goal.

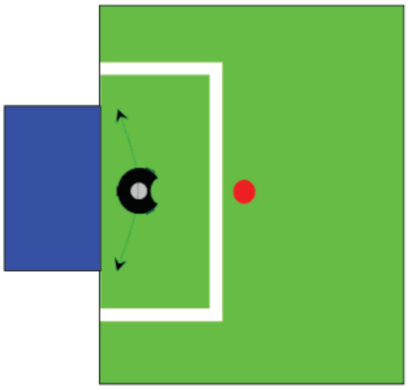

Figure 10 · Golly behaviour - position and states.

B. Attacker Behaviour

The Attacker is the robot that moves more around the field, always seeking the ball. It has two sub-behaviours, when it sees the ball and when it doesn't see the ball. When the ball is not at the robot's sight, the robot searches the ball by moving from one goal to the other in the field centre line. With this behaviour the likelihood of finding the ball is very high. Once the robot finds the ball it changes to the second sub-behaviour which consists of moving towards the ball, when near the ball the robot positions itself at the back of the ball and then moves towards the ball in order to kick. Should there be an obstacle, the robot tries to pass the ball (with a small kick) to the striker. Once it passes the ball to the striker, this robot changes its behaviour to a striker and the other robot becomes an attacker. The communication is fundamental for this behaviour otherwise the two robots become attackers or the two robots become strikers.

Sometimes that happens for some short time although that proved not to be a big problem.

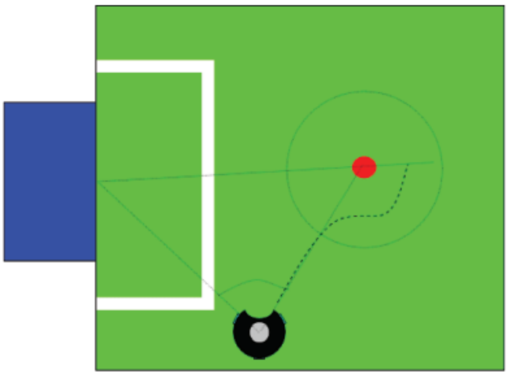

Figure 11 · Attacker positioning.

The robot uses the angle between the goal and the ball to position itself, as well as the distance to the ball. It is important to point out that should an obstacle appear on the robot's way it changes to a different routine in order to avoid it.

C. Striker Behaviour

This robot does not move towards the ball but it moves towards a position on the field where it can see the attacker and the goal in a straight line and without any obstacle between them. Should an opponent robot position itself on these straight lines, the striker has to move to another position. Once the ball is near, it changes to a different behaviour and starts as attacker.

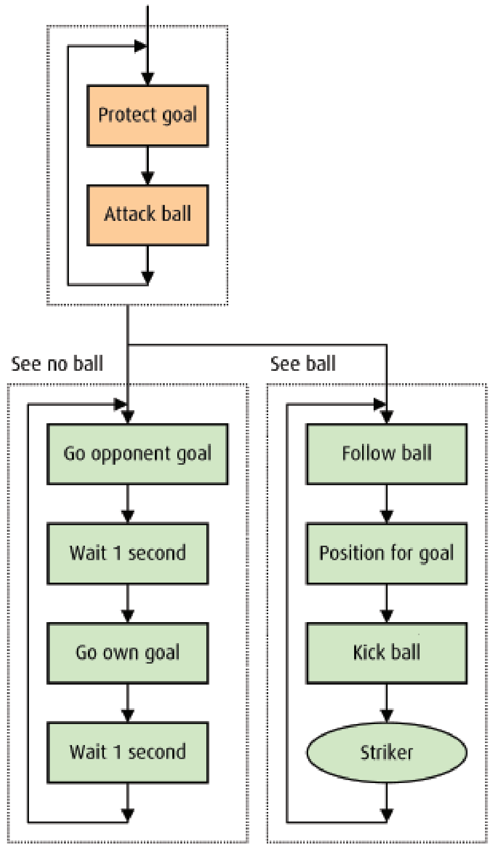

Figure 12 · Attacker stages.

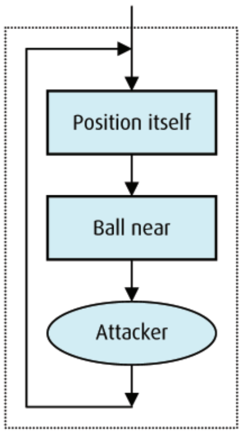

Figure 13 · Striker stages.

D. Robot Localization

The robots use the known field length and the angle to both goals in order to position themselves. Simple triangulation is carried out using these three variables allowing calculating the robot position with an error of around about 10cm. This error is minor and does not influence the game quality, considering that the field is 12 meters long.

A question might arise case the robot does not see the goal. That can happen but rarely since the goal is higher (1 meter) than the robots (0,8 meters). But should that happen, the robot will momentarily not know its position, but through communication it can still play and know approximately where he is.

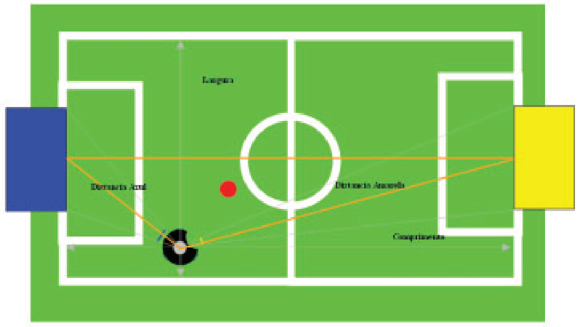

Figure 14 · Robot Localization.

VI. CONCLUSIONS

With these robots this team has been playing with great success. Last year in RoboCup'2003 they were fifth out of 24 teams. Hardware problem occurred which cannot be ignored. This is important to keep in mind, no matter how good the software is, should the hardware fail. This year competition GermanOpen'2004 this team became 3rd after loosing on the semi-final by 2-1 with the champion team. On the Portuguese National competition this team got 1st place, 24 goals were scored and only 4 suffered.

The main advantages are the synchronization of the robots, because each robot knows where the team mates are and what they are supposed to do.

Still mane improvements need to be carried out, especially what concerns the motors speed. These robots can run at 0.9 meters per second at most.

This cooperation technique could be used in more cooperative behaviours applications like the material transportation within an industrial environment (by two or more robots) and on any other multi-agent application.

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