New improvements of MINHO Team for RoboCup Middle Size League in 2003

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Abstract. Although this research group has started a robotic football team in 1998, MINHO team has been participating in RoboCup only since 1999. The robots were completely developed by the undergraduate team members (mechanics, hardware and software), due to budget reasons, and every year new improvements had been made. The team came to a point where new improvements would mean complete changes in the robot design, hardware and mechanics and that meant to build 4 new robots. Being all member of an Industrial Electronics department, our main research areas consist of general electronics, computer vision/image processing, and control. In this paper, the major changes implemented are described and some results assessed.

1 Introduction

RoboCup consists mainly on a scientific challenge created to foster research on autonomous mobile robotics and related areas. But, consistent and successful research is improved on a stable and reliable mobile platform. Standard platforms can be bought off-the-shelf at high prices but due to the peculiar demands of the RoboCup challenge, these platforms always need some extra mechanics and/or hardware, making sometimes easier to build a specific mobile platform that copes with all the rules and characteristics of the game.

Although many teams prefer to buy a standard robotic platform and implement some changes in hardware/software or even some adaptations, Minho team builds their own platforms from scratch with undergraduate students as part of extra curricular work and with reduced budget. This continuous participation in RoboCup has led to many new developments in many fields. In previous years [1][2], the robots used poor and too complex mechanics, which meant that frequently problems would occur. A decision was taken to implement major changes in mechanics and hardware in the robots this year, and to improve the strategy/tactics and cooperation algorithms for next year when RoboCup will be held in Portugal.

The know-how from previous participation was taken into account, and a new design was developed. The old robots were analyzed and a list of disadvantages was created.

Table 1. Old robots disadvantages

Characteristics	Quality	Description
Manoeuvrability	Poor	Two wheels differential drive
Vision system	Poor	2 cameras, one facing 45 degrees
Battery autonomy	Low	About 35 minutes only
Ball control	Poor	Convex arc of 7 cm
Kick	Acceptable	About 30 meters
Operating System	Old	MS-DOS (lack of drivers)
Computer CPU	Busy	Control all hardware

After analyzing this table, the team came to the conclusion that a new design needed to be developed to overcome all these disadvantages.

2 New Design

Since a new prototype was about to be built, it would need some tests beforehand and SolidWorks was the tool used to draw the robot model in three dimensions. This way, every simple part could be properly tested to check its size, operability, its weight, its assembly, accessibility, etc. In order to make this robot as modular as possible, three floors were created. The bottom one would have the motors, wheels, and support the kicker and batteries (all the heavy stuff should stay as lower as possible).

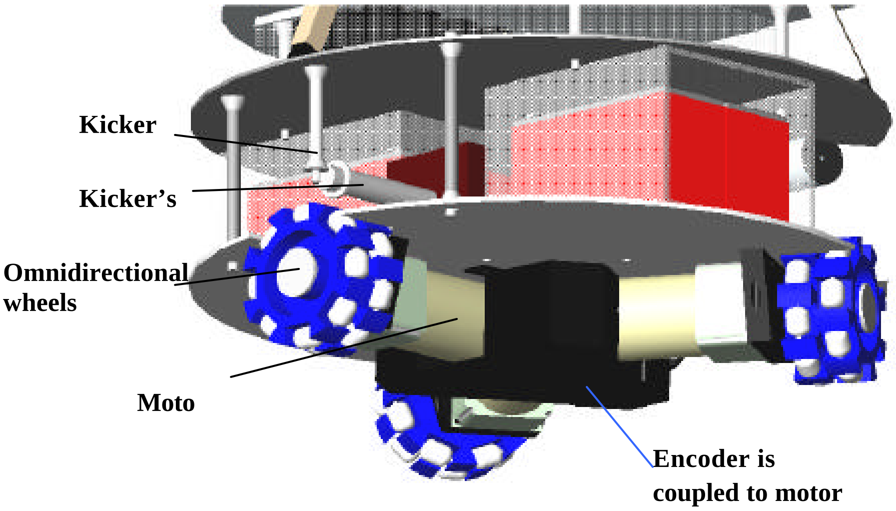

Fig. 1. Robot CAD drawing – Bottom view

The second floor would carry the kicker energy storage and several control electronics boards. The third floor would carry the computer box. With this design everything is fast and easily accessible from the outside without having to disassemble the robot.

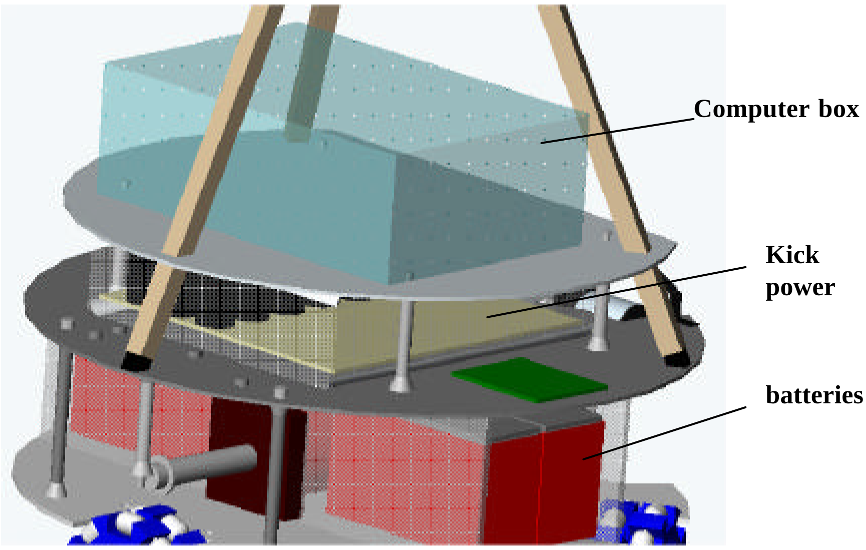

Fig. 2. Robot CAD drawing – Back side

The kicker would be placed on the front side, between the four batteries. Also a protective device was used in order to protect the front motor from strong collisions.

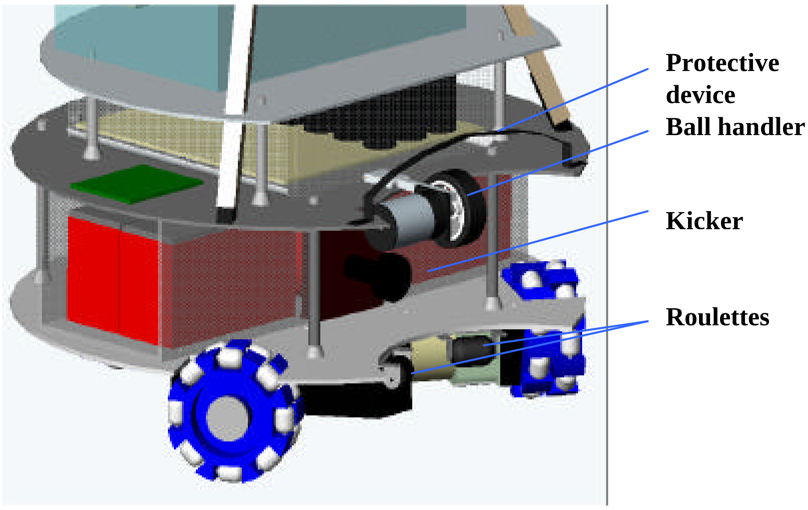

Fig. 3. Robot CAD drawing – Front side

To grab a better view, the vision system should be as high as possible. A tripod was mounted on top of the three floors platform to hold the vision head (analogue camera and spherical mirror). This would allow Omn i-vision.

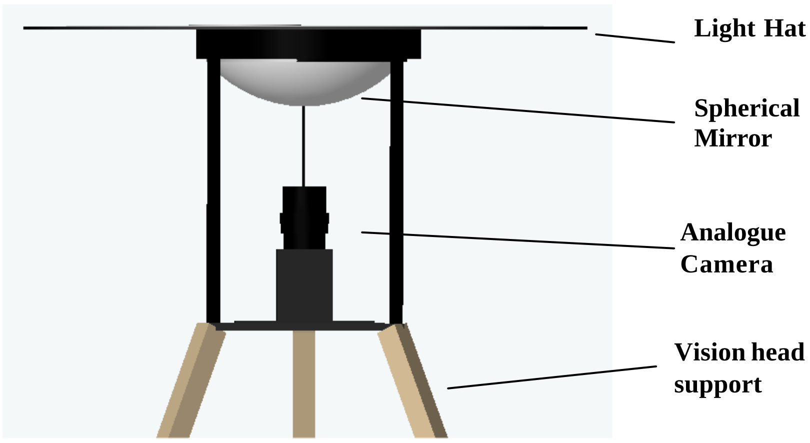

Fig. 4. Vision Head CAD drawing

Since the wheels used were shorter (half the size of the old wheels), this allowed to lower the gravity centre. New stronger and lower consumption 24V motors were used and they were directly coupled to the wheels, reducing mechanics (previous version had external gearbox with complex mechanics).
Infrared encoders and respective electronic were developed by the team. They can read 24 different positions per crankshaft turn. As the ratio is 3.125 and the wheel radius is 50mm, that gives a resolution of approximately 4mm (in straight line, with no load and without slippery).

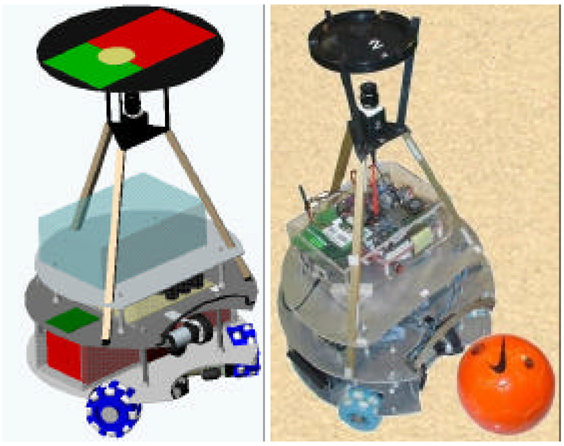

Fig. 5. CAD drawing versus Real Robot

3 Omni Wheels

It is of maximum importance for the robots to move as fast as possible towards the ball in order to control it sooner than the opponent team robots. With the use of Omni wheels (also known as Swedish wheels) there is no need to rotate the robot until it reaches the ball direction, since the robot can move in any direction. Therefore, the decision of using three omni wheels (as shown in **Fig. 6**) was easily taken.

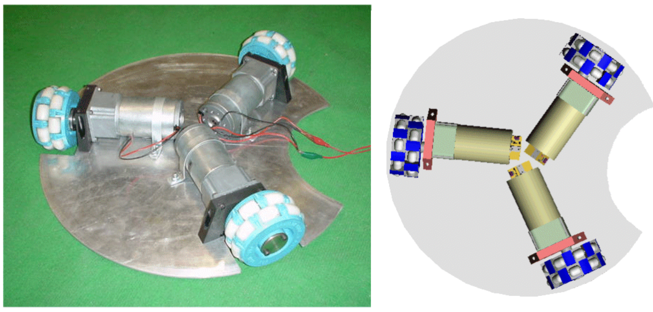

Fig. 6. Three-Wheel drive mechanical construction (physical and CAD design)

These wheels provide simple control and steering, allow extreme maneuverability and speed reaching the ball direction. However, this type of wheels also has brings up other problems like traction and their facility of being pushed by opponents robots. This is the main reason why it is not advisable to use this type of wheels on a goalie.
Previous attempts had been made with this type of wheels and an example is the Artisti Veneti team which already uses an holonomic platform as described in [3].
The motor control is simple. The total platform displacement consists of the sum of three vector components (one per motor) and is represented as a vector in the platform body center.

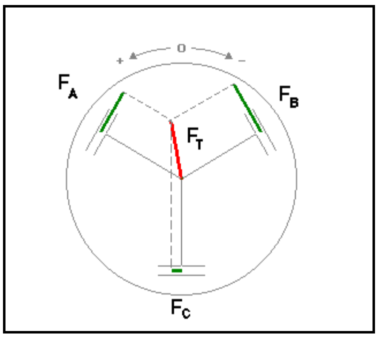

Fig. 7. Motor contribution vector representation for a certain desired movement

In Fig. 7 it is depicted a vector representing the desired movement (F_T in the center); the angle represents the direction and the length represents the speed. In order to find out the three independent motor contributions, this vector is projected on A, B and C axis representing each wheel line of movement. The vectors can have a positive direction (to the left) or a negative direction (to the right) which represent the direction in which the motor has to move (forward or backwards respectively). Should angular movement only be required, identical contributions are given to the three motors.

4 On Board Computer

A Low consumption computer 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 the motor controllers), 1 serial port and a PCI slot. A two PCI raiser is used in order to connect the two boards (standard IEEE 802.11b wireless Network board and a Philips Bt848 chipset based frame grabber). The operating system used is Mandrake Linux and the whole software is written in C language.

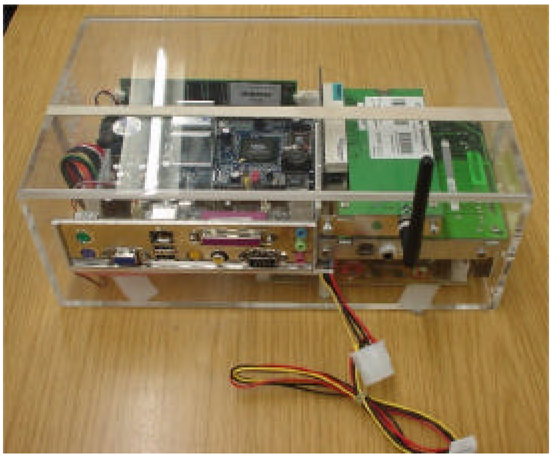

Fig. 8. Computer in a transparent box

5 Kicker

A new magnetically impelled kicker was developed, similar to the previous one but stronger and faster charging. It uses an electric coil, in which a current passes through and attracts a cylindrical iron core. At the other end, a cylindrical shape nylon piece is attached to the metallic core and pushes the ball away.

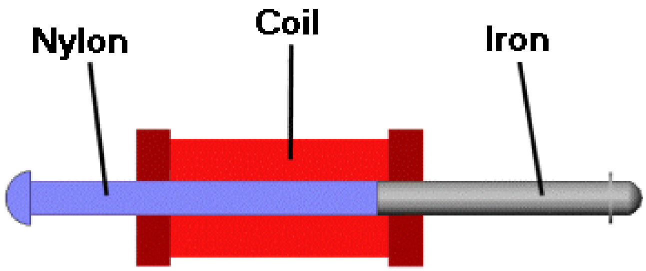

Fig. 9. Kicker coil and core

Table 2. Kicker Characteristics

Characteristics	
Maximum charging time	1.5 seconds
Equivalent capacitance	833 μF
Coil inductance	55 mH
Maximum energy consumption by kick	54 Joule
Weight	2 Kg
Ball distance	Over 50 meters

6 Ball handler

A new technique was developed in order to control minimally the ball. As the rules say that the ball must roll, a new device was built in order to make the ball roll. A model car wheel type rotates when in contact to the ball and it makes the ball roll. In order for the kick to be efficient the ball should be at a certain distance from the kicker. That is achieved with this device, which maintains the ball always close to the kicker and rotating ready to be kicked. This device allows other robots to easily remove the ball from it being only necessary to touch it.

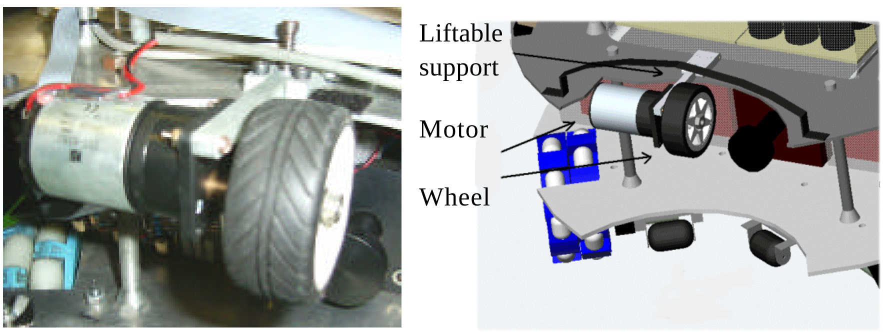

Fig. 10. Ball handler (real versus 3D drawing)

This motor can rotate at different speeds which makes it useful for any kind of ball. During the game it is turned on only when the ball is near (about 20 cm) and off as soon as it loses the ball. This way battery energy is saved.

7 Vision

Although the same spherical shape mirrors are used, they are placed in a different orientation. The new robot design allows the camera to face upward and the mirror to face downward (Fig. 4). In previous versions the mirror and the camera were in a similar position but pointing slightly to the robot's front, since the back of the robot would cover part of its field of view.
With this new orientation real Omni vision is now achieved, being possible to see at a distance of about 8 meters for goals but only 2 to 3 meters for the ball. The image is also centred which simplifies the software build up.
New image processing routines were developed and these allow most of the setup without the need to re-compile the software. Users without much programming knowledge can easily add virtual sensors to the game strategy, just by editing a parameters text file. The main routines are *Histograms*, *Areas* and *Colours*. Parameters like the window coordinates, the threshold and the required colour are only examples.
Football field Lines detection is carried out as first step to find the location of each robot as described in [4]. This technique uses a co-linearity detection algorithm after applying a convolution mask to the image.

8 Robot Electronics

Since MINHO team belongs to an electronics department, all the electronics are designed, developed, built and tested by the team members. The boards were specially built for this robot and proved feasible. The main electronics developed consist of:

- A peripheral's board – where all the other boards connect to. This board is linked to the computer through the parallel port. Similar boards exist in the market but they proved more expansive, showed problems with different earth's, and the computer motherboard had no free PCI slots for them.
- A motor control board - One board per motor is used (3 per robot) and it consists of a Micro-controller which, after a computer output, defines the motor direction and speed by generating the PWM through a control algorithm on the micro-controller. Since the software to control the motor is in a PIC, it releases the computer microprocessor for other tasks. It also receives the infrared encoder reading which when compared with the required speed, generates the error and is then fed to the speed control algorithm. An electric current sensor is also embedded on the circuit board which detects and limits high currents (when a wheel is stuck for example). When that happens, the motor power supply is cut. This avoids the motor to break down and avoids also strong collisions with opponents' robots.

- Ball handler board – responsible for turning on and off the rotation of this motor and also to control its speed.
- Kicker brain – responsible for receiving the information from the computer and also for the correct charging of the capacitors.
- Kicker power – responsible for discharging the capacitors and kicking the ball.
- A data acquisition board – Which reads many information from the batteries (its voltage), kicker board (its state), ball handler board (current used), etc.
- Other electronics – for several other tasks like switches, LED's, cabling and computer power source.

Below is a diagram of the most important hardware on the robot.

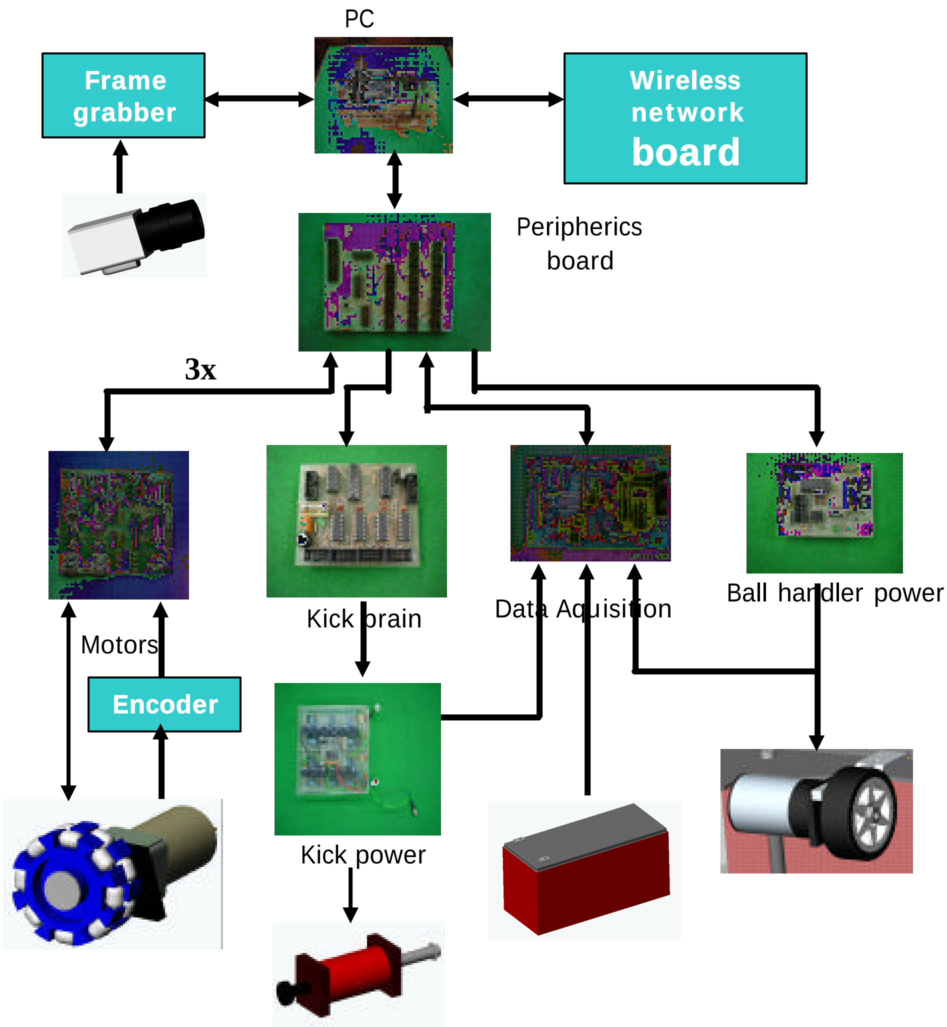

Fig. 11. Algorithm of the motor control boards

All the hardware built proved very stable and reliable. Although these boards were specially built for these robots, they could be used in any industrial environment.

9 Software Interface

The image the camera sees is a circular one following the spherical shape of the mirror, but through software it is then showed on the screen in a different way. The image is opened and stretched as if the camera had a cylindrical CCD looking all around. Fig. 12 shows the robot interface software. The top image consists on the real video that it grabs in full colour. The second window shows the top video image but after filtered to the desired colours. It also contains all the virtual sensors (obstacles, goal areas, ball, etc.). The third window consists on the results of the virtual sensors. Obstacles are represented as crosses, coloured histograms represent the position of each colour entity (goals and ball) and their respective values.
The fourth area shows several variables of the program, like network status, distances to objects, hardware status, step in the program, number of frames, etc.

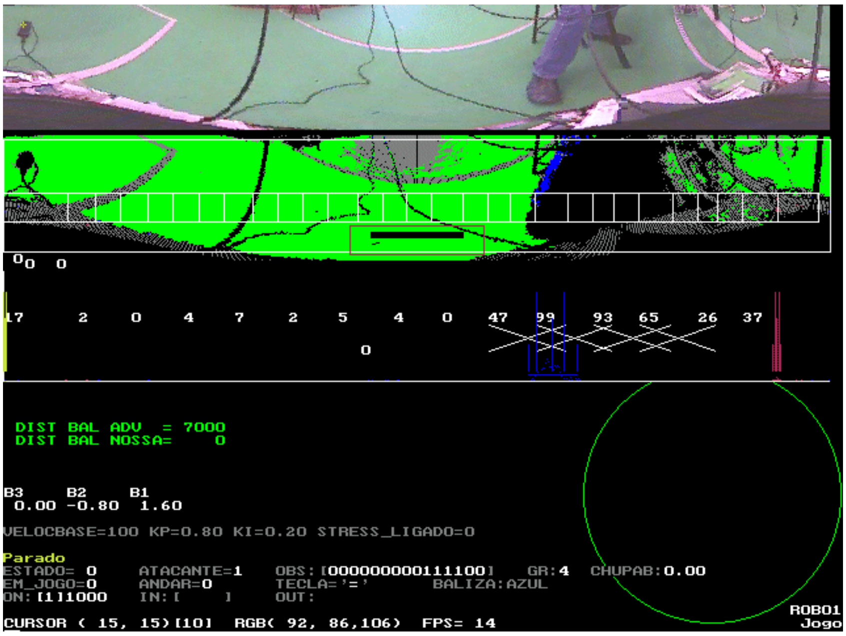

Fig. 12. Software interface

The remote computer has an easy interface with 4 keys. One to make the robots play against the yellow goal, another to make them play against the blue. The other two keys are the START and STOP of the game. This software also receives all the communications between all the robots and print it on the computer screen for debugging and output purposes.

10 Conclusions

MINHO team design and developed a new robot team from scratch. These robot use Omni wheels, which allows easier control and maneuverability. The robot's gravity center was lowered and the weight reduced. New low consumption and strong motors were used and directly coupled to the wheels reducing mechanics complexity.
The main drawbacks from the previous robot were solved. These robots proved to be efficient and reliable enough to continue research in new areas rather than continuing developing electronics. The main conclusions are described below:

- Omniwheels were used and proved to be an important improvement in the robot's performance. However, these wheels are very slippery. Similar wheels with higher grip (maybe in rubber) could be the solution.
- Due to the wheels slippery no stress detection could be achieved. This raised other problems, for example when the robots got tangled, because the robot could not get ride of the other obstacles.
- The kick proved in the competition to be the strongest of the tournament. It is very strong but also controllable, which means that the kicking power is set up by software. The minimum kick the team reached was about 10 cm. It charges completely in about 1,5 seconds and it uses very little energy
- The robot vision is acceptable but only in the first 2 to 3 meters. Farther than that the ball becomes so small that it is invisible to the camera after the filtering. New mirrors with a parabolic shape are needed.
- The use of analogue cameras showed much noise on the image captured due to the analogue to digital conversions in the frame grabber. With the use of a digital camera (perhaps a USB 2.0 or FireWire (IEEE1394)) could reduce noise and get a clear image. These cameras also waste too much energy.
- The ball handler proved to be revolutionary. With this technique it is easier to make passes, to dribble an opponent robot and makes the game more enjoyable. This was the first time such device was used in middle size league.
- Comparing to the old generation of robot, these new robots autonomy increased considerably. The computer used only one battery which lasts for over 3 hours. The motors and kicker use 3 batteries and these last for over 2 or 3 games.
- The computer processing decentralisation was another good solution. Leaving the motor control for a PIC (one per motor) freed a lot the computer processor for the most computing dependent tasks.
- The image processing and game strategy software proved very simple, easily parameterisable, which leaving space for next year improvements like passing the ball and learning. The colour calibration is now much easier, simpler and faster.
- The computer motherboard used runs at a 933MHz speed and controls the game strategy and wireless communications. Mandrake Linux operating system is used and that permitted a reduction in code of about 80% compared to the previous robots.
- Now that new and reliable robots were built, it is time to think in future improvements. These should be in the area of image processing. Perhaps an

algorithm able to recognise entities through its shape. Another example could be the ball pass and more efficient dribbling.

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