Hardware and Software of the FU-Fighters 2003

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Abstract

The FU-Fighters will take part this year in the small-size league RoboCup tournament for the fifth time since 1999. We will show new robots at the competition. The main changes to the previous system are the addition of vertical and horizontal dribbling bars, the use of a new electromagnetic kicking device, and color tracking with two cameras and two framegrabbers controlled by a single dual-processor computer. In this report we report on these changes and on what we have learned while developing the 2003 team.

1 Fifth participation at RoboCup

The FU-Fighters are a team of small mobile robots that take part in the anual RoboCup competition. The robots have a maximum diameter of 18 cm, are omnidirectional and have a kicking device. We have produced several generations of robots since 1999 [Ackers et al. 1999, Behnke et al. 2000b, Rojas et al. 2001].

First generation. Two-wheeled robots with a rotating bar as kicking device. This was the first really powerful kicker in the small-size league and was later adopted by several teams. These robots played at RoboCup 1999 and, improved, at RoboCup 2000.

Second generation. Smaller two wheeled robots with an electromagnetic kicking device. These robots were used in our lab, but were not used for competitions.

Third generation. Robots with a rotating kicking device enclosing the robot. The robots were extremely fast, but the kicker was not very effective. It is however, a very interesting mechanical construction.

Fourth generation. Omnidirectional robots with a rotating kicking device. The omnidirectional wheels are of-the-shelf components used also by other teams at RoboCup 2001 in Seattle. The fourth generation included also robots with local vision, that is, with a video camera used for localization [Hundelshausen et al. 2001].

Fifth generation. Omnidirectional robots with special wheels, made of many smaller wheels. These wheels provide better grip, are more energy efficient, and can transport the robot at higher speeds than the commercial wheels and have been adopted by several teams. The robots used a new microcontroller (Motorola HC12) and a new chip for wireless communication. These is the fastest generation of robots that we have built to date, and they were also the fastest robots present at the RoboCup competition in Fukuoka.

Sixth generation. Omnidirectional robots with the FU wheels, electromagnetic kicking device, and dribbler bars. Although the dribbler was introduced by the Cornell team since 2000, we had resisted using it in our robots. Since future rules will eliminate the sides of the field, dribbler bars provide a huge advantage for a team and we have now included them in our design.

The pictures below provide an overview of the robots that we have built in the last five years.

First generation (1999)

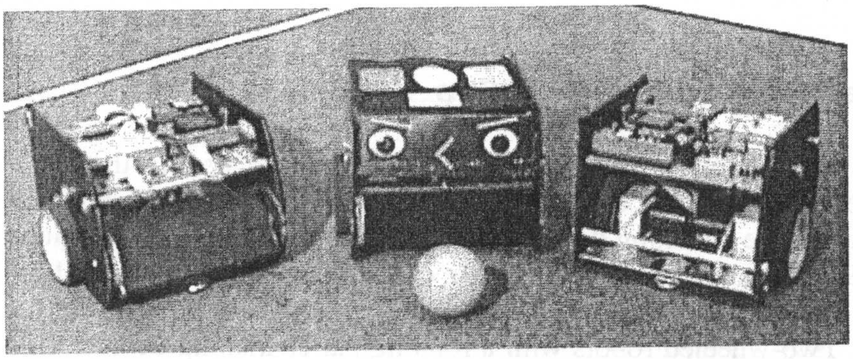


Figure 1: Differential drive, rotating shooting device, 8-Bit microcontroller, not very fast.

Second generation (2000)

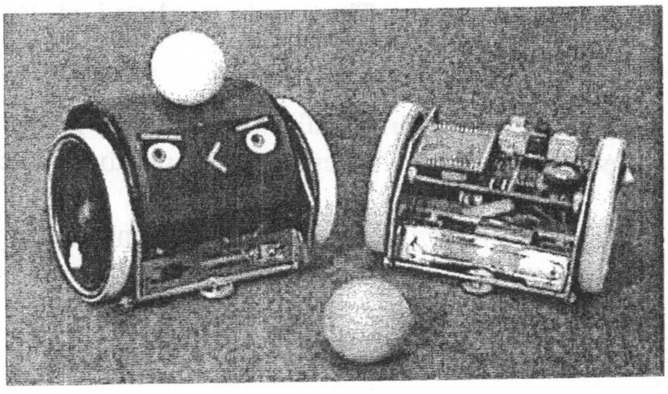
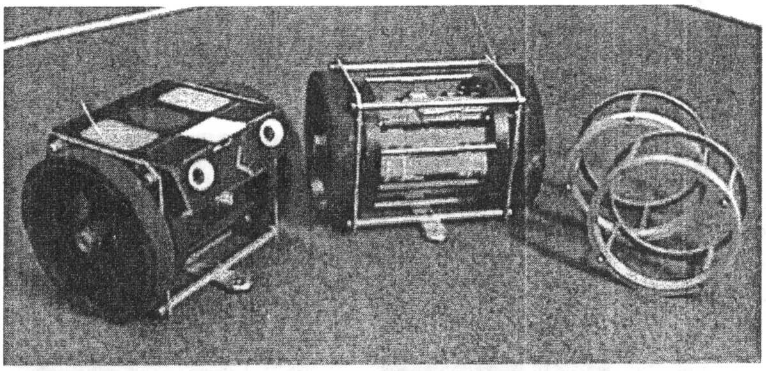


Figure 2: Small, fast robots with electromagnetic shooting device. Miniaturized version of the electronics. The robots were used in combination with our first generation robots.

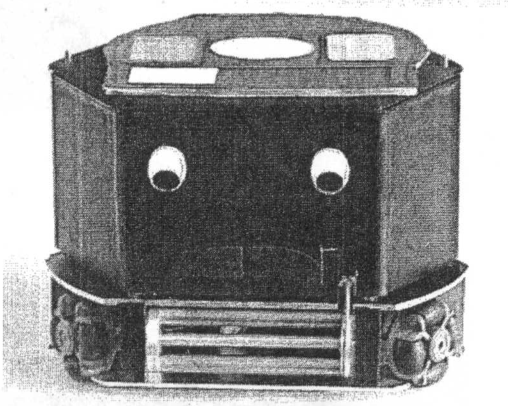


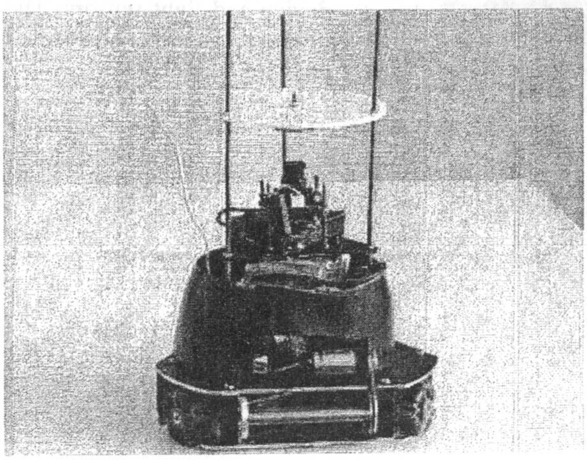
Third generation (2000)

Figure 3: The robot is contained inside a rotating barrel which acts as shooting device. These were extremely fast robots.

Fourth generation (2001)

Figure 4: New 16-Bit microntroller, omnidirectional drive with off-the shelf-wheels, new 16-Bit microcontroller, improved computer vision system. The robots played in mixed teams with the other generations and in teams of exclusively omnidirectional robots.





Fourth generation with Local Vision (2001)

Figure 5: The basis of the robot is omnidirectional. The camera points towards a parabolic mirror. The video image is transmitted to an off-the-field computer that processes the image and transmits the commands for the robot.

Fifth generation (2002)

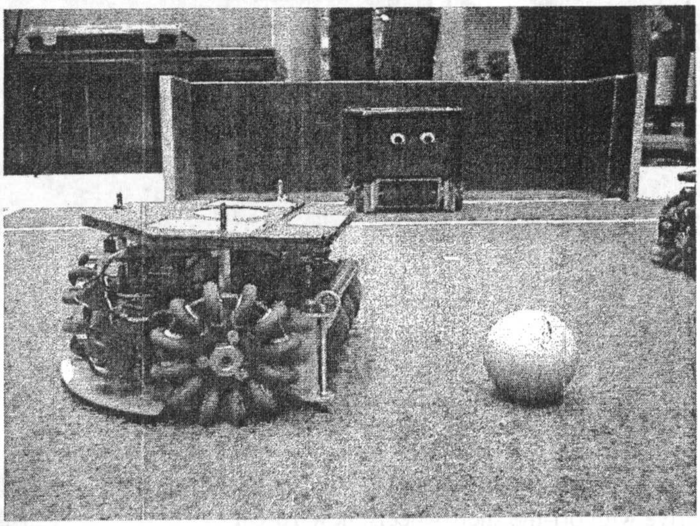


Figure 6: Omnidirectional robots with new wheels, new microcontroller, and new wireless communication chip. The robots were the fastest at RoboCup 2002.

Sixth generation - precursor (2003)

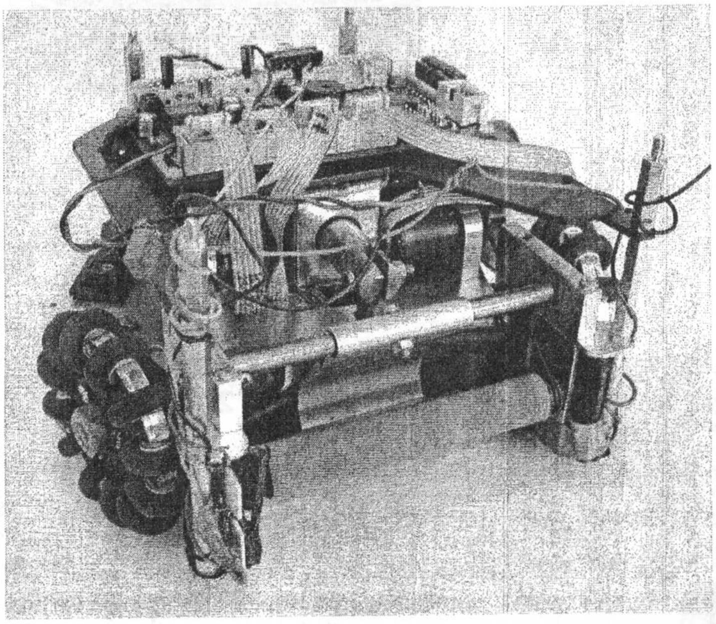


Figure 7: Precursor of the last and current generation. Omnidirectional robots with a horizontal dribbling bar, electromagnetic linear kicking device and light sensors. The dribbler can be controlled as an extra motor.

Sixth generation (2003)

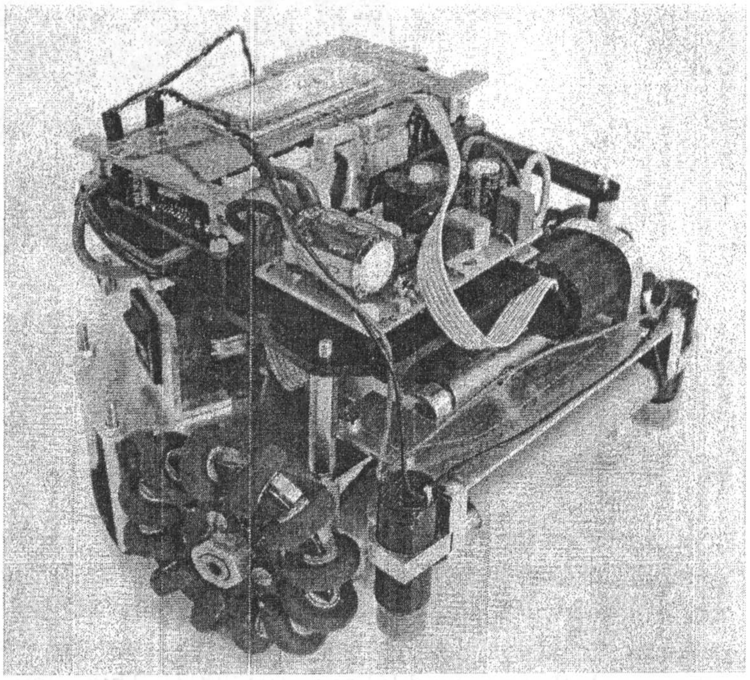


Figure 8: Current generation. Omnidirectional robots with a horizontal active dribbling bar and passive one, electromagnetic linear kicking device and vertical side dribblers.

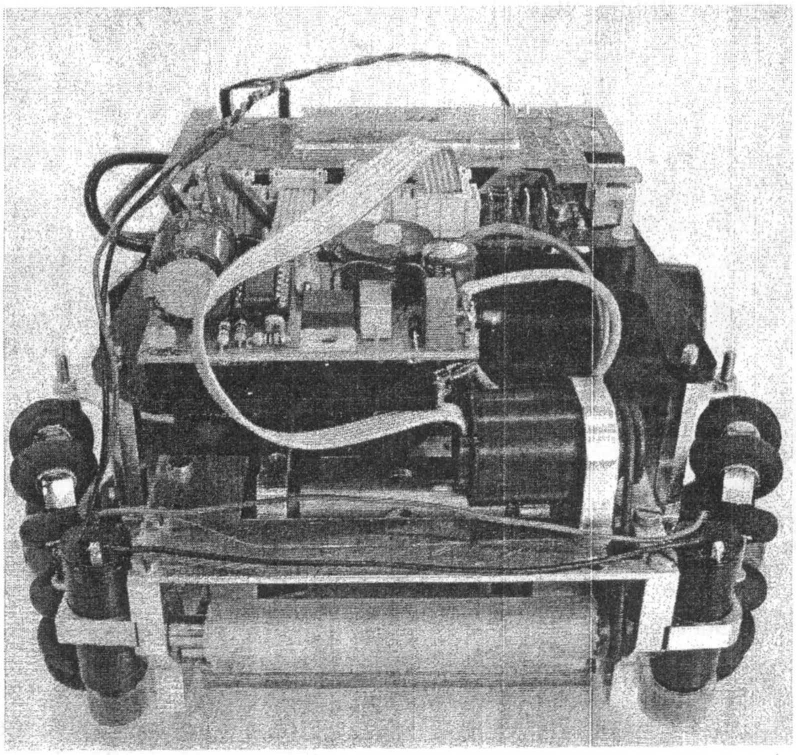


Figure 9: Frontal view of the new robot.

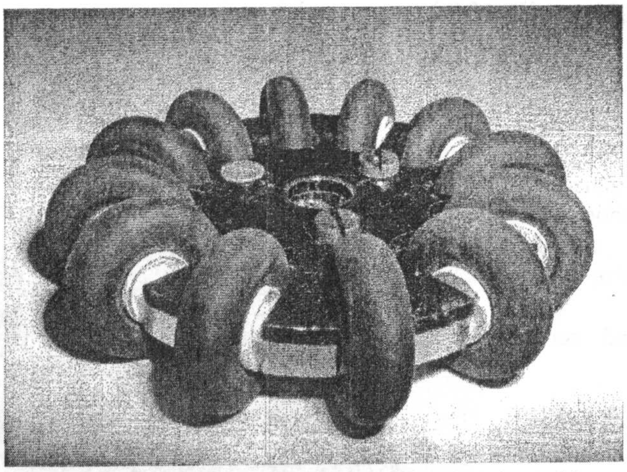


Figure 9: The FU Fighters Omnidirectional Wheels, already adopted by several teams

2 Mechanics

The speed of the robots built in 2002 made us modify some parts of the control system in order to be able to track them. The lowest level of the hierarchy in our control software was transferred to the microcontroller in the robot. Also, we trained the vision and control system to learn the response of the robot to the commands that we send [Gloye et al 2003]. This allows us to track different types of robots with minimal adjustments in the vision and control routines. We use the same reactive control framework that we introduced in 1999, improved with several features [Behnke et al 2000a, 2000c].

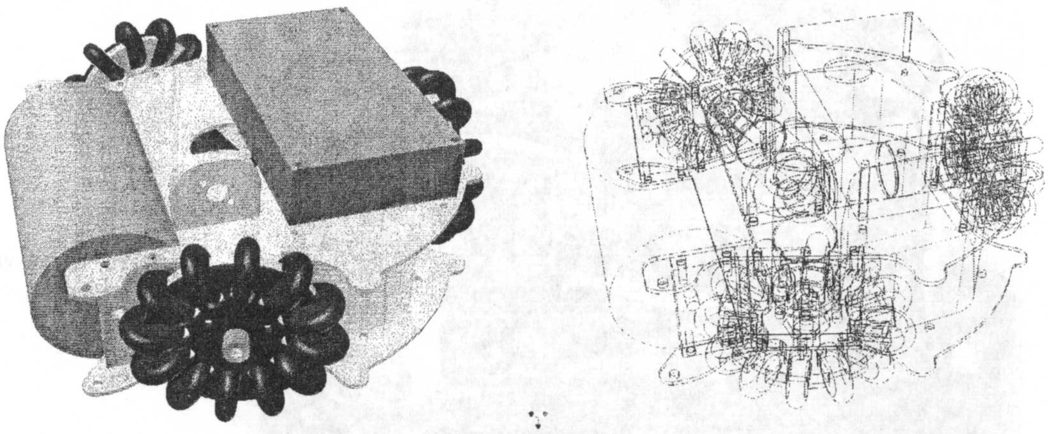


Figure 10: Our robots are fully designed with a CAD System

We have made the transition to full automatic CAD design of our robots. The first generations of our robots were built in a traditional way, doing some design in the computer and some manual adjustments. Now, our robots are created using a

CAD system. The specifications for the parts are transmitted via e-mail to the Max-Planck-Institute or to commercial companies, which mill the parts for us. This is an important step towards the development of a generic robotics platform for the league, since the design can now be adopted by any team willing to compete in RoboCup. The specifications of our team will be released during 2003, together with the full documentation of mechanics, electronics, and computer vision software.

The chassis of the 2003 robots is based on the chassis of the 2002 robots, but many modifications have been made. We are using the same kind of wheels introduced by us in 2002, but we added a horizontal dribbling bar, for giving the ball spin against the robot. There is a second bar, behind and below the first dribbling bar, which stops the ball from going below the robot. Our robots are not as heavy as the robots of other teams, so that the robot could actually "step onto" the ball and lose it.

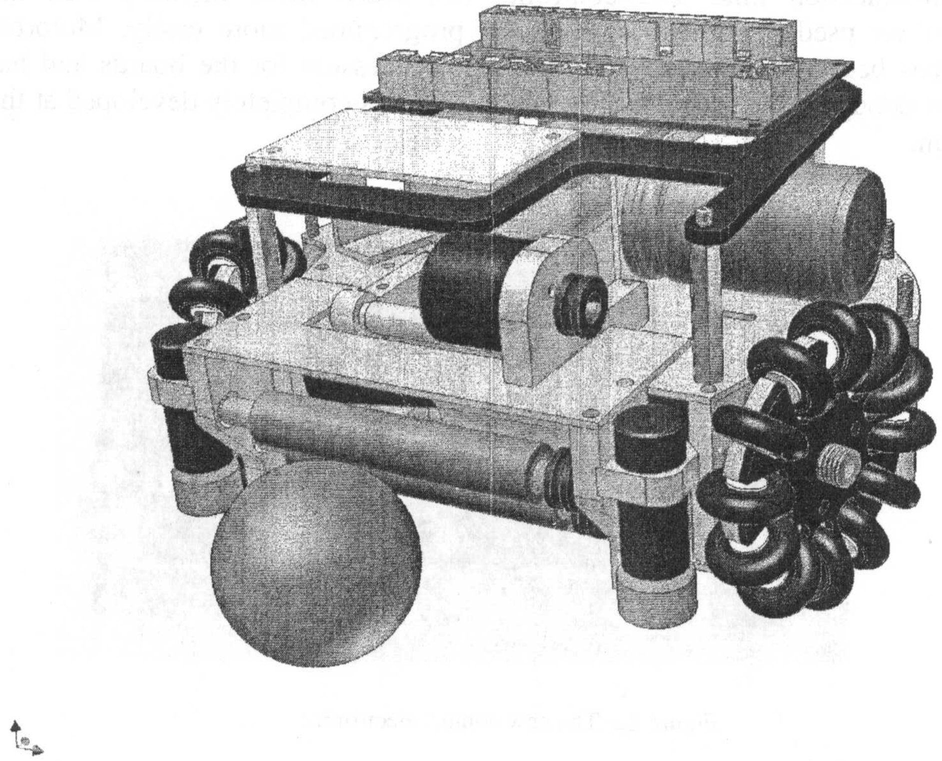


Figure 11: Our 2003 robot CAD design

We also added vertical dribblers to the robot, one vertical dribbler on each side. The purpose of the vertical dribblers is to keep the ball under control, preventing it to roll to the side. This can happen when the robot turns around while driving. The vertical dribbler gives the ball some spin towards the center of the horizontal dribbling bar.

We have a new kicking device based on an electromagnet. The electromagnet pulls a metal rod, which in turn pulls on a lever that pushes a kicking bar. The electromagnetic kicker is not as hard as the rotating kicking bar we have been using for the last years, but is the only possible way to shoot now that a horizontal dribbling bar has been put inside the robot.

The electromagnet is activated with the charge from a capacitor, which is loaded at 60 Volts. A step-up controller has been added to the robot electronics in order to rise the voltage level from 12 to 60 Volts.

3 Electronics

For the fifth generation of our small-size robots, we designed a new control board. We are now using the HC-12 microcontroller from Motorola. The chip allows us to drive up to four motors, count the ticks produced by the encoders and control the communication link. The controller has much more memory than the controller we used previously and can be programmed more easily. Motorola Europe has been providing us with the microprocessors for the boards and has helped us debugging the system. The new board was completely developed at the FU Berlin.

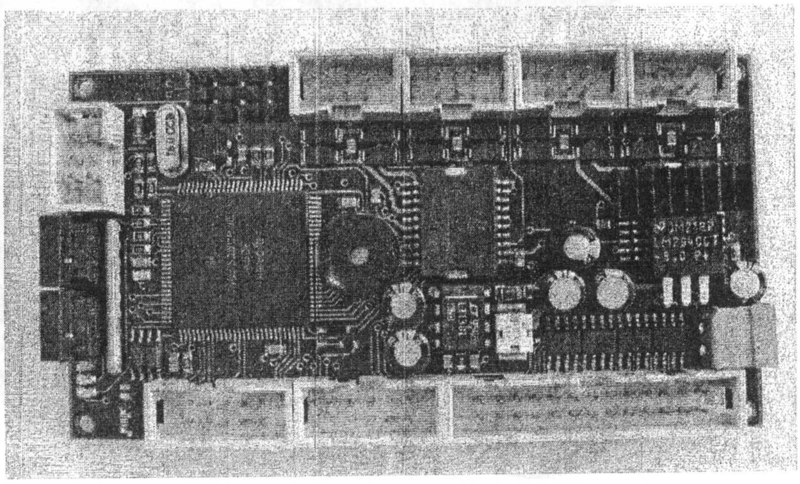


Figure 12: The new control electronics

We changed the communication module in our latest small-size robots. We had been using the SE-200 module from Siemens, but its speed was limited. Our new TX3-RX3 Radiometrix modules provide greater speed and two different frequencies that we can use. Figure 13 shows our communication board. Different communication boards can be piggy-backed on the main electronic board so that we can upgrade the electronic. In Italy, we will have a choice of using this Radiometrix modules or new Bluetooth chips that have just been incorporated in our design. The advantage of the Bluetooth chip is that it gives us a way of sending information from the robot to the control computer.

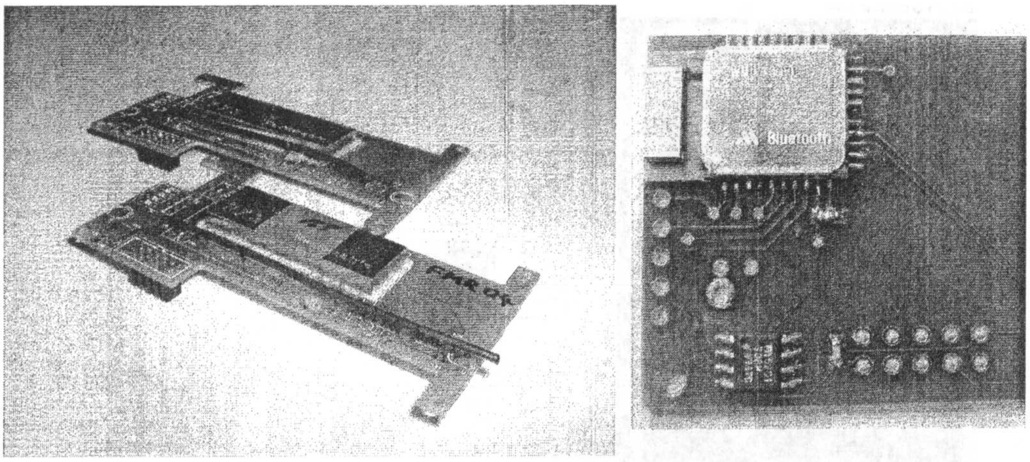


Figure 13: Radiometrix modules and the Bluetooth chip

The microcontroller used for our 2003 robots is the same HC12 Motorola chip used in 2002. We have some new processors, which are clocked faster internally, but the control board remains essentially the same.

4 Vision with two cameras

The main improvement to the vision system has been adopting two cameras as our new vision sensor. The field is split among the two cameras – each one provides a view of one half of the field, with an overlap in the middle. The overlap is necessary for handing over a robot or the ball from one camera to the other. The vision system, while tracking a robot, detects if it changing side and alerts the tracking module for the other side. In the middle of the field, both cameras and vision modules track the same robot simultaneously. The position of the robot is reported as a weighted average of both vision measurements. The weight for a side falls from 1 to 0 when the robot leaves that side of the field and goes through 30 centimeters more.

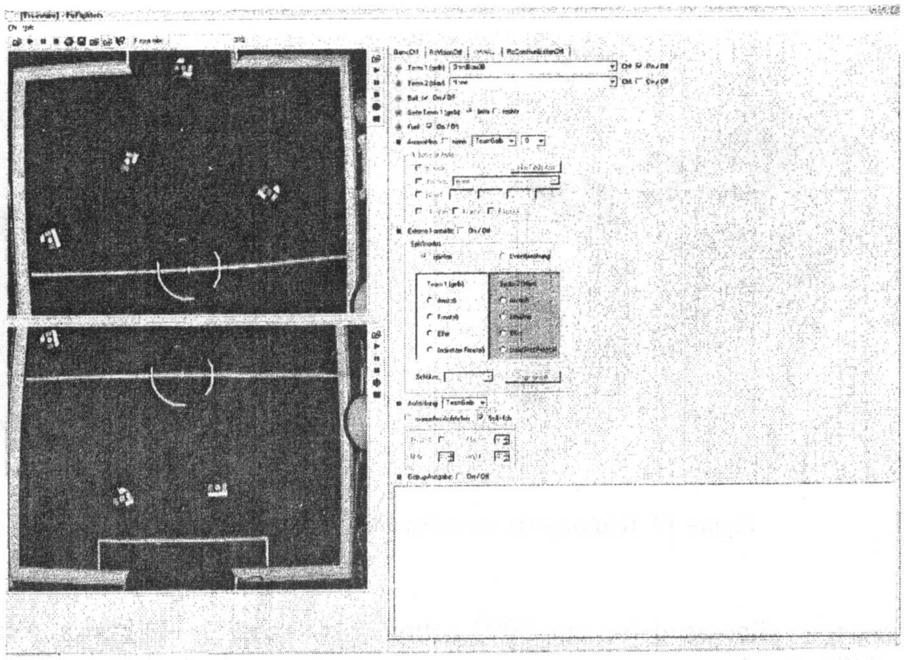


Figure 14: The view from the two cameras. Each camera sees a half of the field and 30 centimeters more.

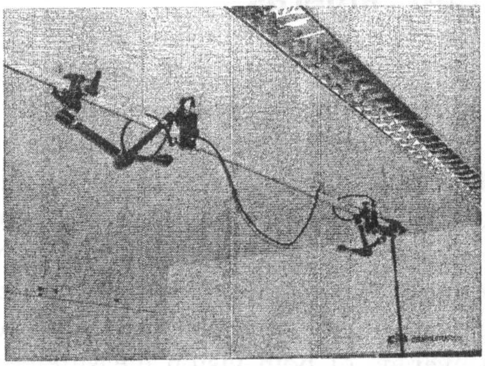


Figure 15: The two cameras mounted in our laboratory

5 New rules – new behaviors

The control software for our robots was upgraded during 2002 and 2003 in two significant ways. First, the code was reorganized to make it more secure against programming errors. Second, a simulator was added, that makes easier to test new behaviors. We have also added a new 3D-visualization feature which can replay a game from the perspective of a virtual camera on the field.

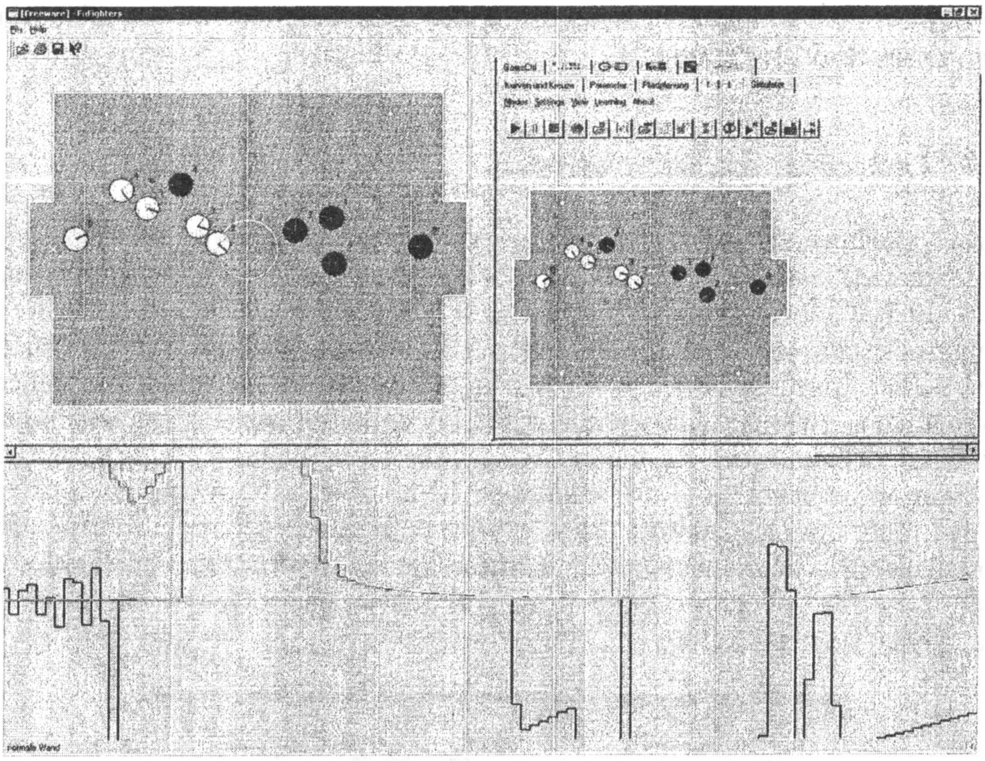


Figure 15: The view of the control cockpit. Left, the view of the field, right the view of the simulator.

The new rules for the 2003 competition do not allow to touch the robots or the computer during a game. The robots have to assume their positions autonomously. This means that several new behaviors had to be programmed:

a) Automatic positioning for a free kick.

When defending, our robots try to form in front of the ball, in order to prevent a direct kick to goal. When attacking, our robots disperse on the field and try to receive a pass from the kicking robot, which also has the option of kicking directly to goal.

b) Automatic positioning for a penalty shot.

The robot takes its position as kicker automatically and shoots, trying to prevent the goalie from reaching the ball.

c) Automatic positioning of the goalie.

The goalie assumes the best position possible, when trying to prevent a goal from free kick or before a penalty shot is taken. We have also developed a new goalie which can absorb the ball and release it in less than 15 seconds. The goalie tries to avoid releasing the ball too hard, so that it wont pass the field half-line (this would be a transgression of the rules).

6 Learning experiments

During 2002 we started experimenting with automatic training of robots using reinforcement learning. It is difficult to adjust the parameters of a robot by hand, specially fast moving robots. Therefore, a better approach would be to let the computer experiment and find the best parameters for a certain robot. Our first experiments were concerned with driving a robot from one point to another in minimal time, making it decelerate optimally so as to arrive at the desired spot without overshooting or oscillating. We will continue doing these Reinforcement Learning experiments and we will hope to be able to show an automatically trained robot during RoboCup 2004. At least one aspect of our current robots is learned using a neural network and linear predictors: the future dynamics and position of the robot, predicted from past vision data. This work is reported elsewhere [Gloye et al. 2003].

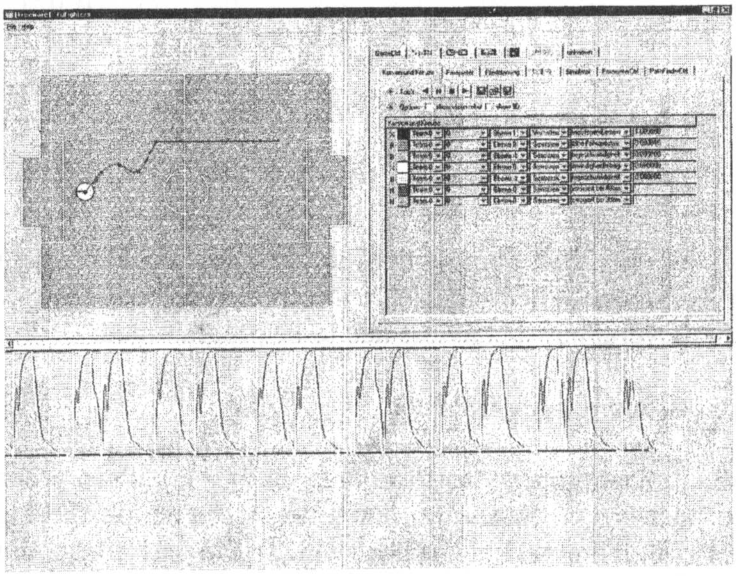


Figure 15: A robot learning to drive and stop optimally.

7 Summary

The new generation of FU-Fighters robots consists of the most complex robots we have built to date. The increased number of features led to an undesirable effect: the robots are now bulkier and the motors tend to get hot during intensive driving. We will have to upgrade the motors in the future or shed some weight from the robots. If dribbler bars are outlawed from the competition, the robots could become lighter again.

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