VISION SYSTEM AND GAME - STRATEGIES FOR ROBOTSOCCER

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Abstract: The game robot soccer provides a good opportunity to implement and test the cooperative group behavior of mobile robots. In this contribution a robot soccer system (Kopacek, 2002; Putz, 2004; Würzl, 2003 and 2005) will be described. The new software mainly consists, as usual, of a vision system, a communication module and a game strategy module. For the new system robots were developed and a vision system with a digital camera was implemented. The strategies for this new Multi Agent System (MAS) will be highlighted in this paper.

Keywords: Design, Electronics, Multi Agent Systems, Mini Robot, Mirosot, Robot Soccer

1. INTRODUCTION

For the robot soccer program it makes no difference if there is either a real mini robot or a simulator. But indeed for a completion in robot soccer a perfect working robot is a fundamental part of the whole system(Putz, 2002 and 2004). The soccer playing mini robot has to fulfill his task as exactly as possible without any controlling help from the main program. This results out of three main facts:

- A sampling time of even 20 ms is much too long to control a robot driven by DC-motors.
- The dead time between a picture and the reaction of the robot.
- The vision system is inaccurate too.

A robot has to have an on board controller. The strategy of such a visionbased Multi Agent System has to take care of these facts and some future prediction algorithms have to be developed.

2. HARDWARE MULTI AGENT SYSTEMS

There are two possibilities to realise a Hardware-MAS:

- vision based
- autonomous

In the following a vision based Hardware Multi Agent System which is used in the Mirosot robot soccer-category is described.

Fig. 1 shows the typical structure of a Mirosot-robot soccer system. This structure and the mobile robots are discussed in detail.

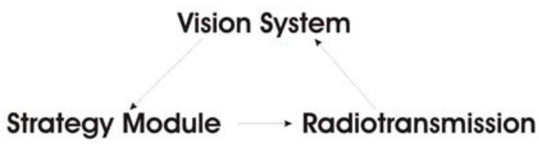


Fig. 1: Structure of a Robotsoccersystem

3. MINI ROBOTS

According to our experience at the World champion ships in Brazil’99, Korea’02 and Vienna'03 and at the European champion ships Slovenia'03 and Germany'04 a competitive Mirosot soccer robot has to fulfill the following requirements:

- fulfill his task as exactly as possible
- stay on its given trajectory
- control itself

- Therefore it needs a possibility to measure its movement
- fit into a cube with an edge length of 7.5cm
- signal if the power supply is empty (lamp)
- an easy way to change the battery
- a low center of gravity
- a separate power electronics for controlling
- a possibility for driving the ball
- broad wheels
- roller bearings
- a single stage gear
- a modular and open architecture
- reach a speed up to 3 m/s
- an acceleration of more than $6 m/s^2$
- a tolerance of motion less than ±0.5cm/m

A mini robot consists of the following parts:

- Power supply
- Two DC - motors with digital encoder
- Single stage gear
- Two wheels
- Micro controller for controlling the speed of the DC - motors
- Power electronic
- Radio module for communication

The goal was to develop a modular mini robot. Due to the modular architecture the possibility of adding sensors is very easy.

Fig. 2 shows the result of these lists (Hager, 2003; Putz, 2002 and 2004).

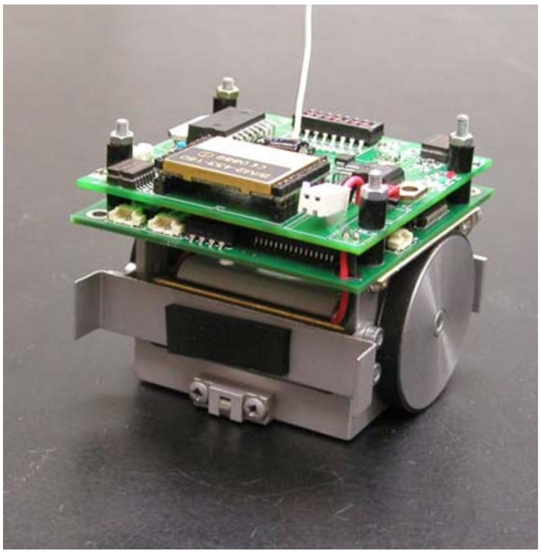


Fig. 2: The Mobile Mini Robot

4. VISION SYSTEM

The software package of a robot soccer system consists of three parts, namely the vision system-, communication- and strategy-module(Putz, 2004; Würzl, 2005). The software package is necessary to control the robots. To successfully compete in robot soccer tournaments, a team's vision system has to be reliable, fast (real time) and accurate. Vision system means detection and recognition algorithms to handle the movement of multiple mobile robots in a dynamic and noisy environment. All calculations related to the vision system performed in the host computer. The task of the vision system is to determine the position of the objects. The colours are used as major cue for object detection. In most cases the camera delivers 30 to 60 either half or full pictures to the frame grabber. Analog CCD-Cameras have different time intervals between two pictures. The time interval is therefore not constant. Digital cameras do not have such a problem, but they are relatively expensive. The old IHRT Vision system consists of an analog colour-CCD camera, a frame grabber which generates a frame each 33 ms and an image processing module which detects and tracks all the objects from the playground. The new IHRT vision system uses a digital camera.

Each robot is marked with one team colour patch and the robot colour patch. The distance between them is fixed. Because of the inherited noise, false detection occurs. It is eliminated by filtering off the ‚salt and pepper‘ noise, meaning the colour patches not matching those on the robots, and discarding the colour patches that do not respect the distance between the team and robot colour.

The speed of the vision system plays an important role. There is a time delay (approx. 60 ms) between taking a picture with the camera, image processing, generation of motion commands, sending commands via radio, reaching the motion commands and a moving robot. In the timeslot between taking visual information and carrying out the command the robot is moving in somewhere. Assume that the robot moves at a maximum speed of 3 m/s and the time delay takes 60 milliseconds, the difference between robot's position when the camera takes a picture and robot's position when the robot starts to move is almost 18cm. Furthermore the time between new data provided by the vision system is not constant. Therefore it is necessary to have a fast as well as an exactly working vision system.

The requirements for the new vision system were:

- full picture intstead of half-picture
- progressive camera instead of interlaced
- higher resolution
- higher refresh rate
- lower system load of the host computer
- extensibility of the hardware in future

It is not suitable to work with the analog system anymore. Therefore a new digital vision system was developed.

Comparing the analog vision system described above and the digital vision system, it is

- 5 times faster than the analog system
- more accurate and
- easy to handle by setting the colours for different ambient light conditions.

The disadvantage is that the digital vision system is very expensive.

Fig. 3 shows the Graphical User Interface. It is possible to see the clear picture of the playground (size of the playground 280 cm * 220 cm). The camera is mounted at a height of 2.5 m over the playground.

The IHRT-vision system is able to use 2 different colour models:

- RGB (red-green-blue)
- HLS (hue-lightness-saturation)

The detection algorithm:

- determines ranges of RGB-values or HLS-values of the searched objects
- decides if the single patches fulfill some rules like the distance between single patches or the maximum size of a patch
- merges the single patches into a single object
- transforms the calculated pixelpositions to playground coordinates.

Fig. 3: Screenshot of the IHRT-Vision system

5. STRATEGIES

The strategy of such a Hardware-MAS like robot soccer has many tasks to perform:

- position functions (to reach a position very fast and exact)
- team lineup
- attacking
- defending
- prediction (of the ball)

Fig. 4 shows an attack kick (Putz, 2004; Würzl, 2003 and 2005). The kick uses only lines and circles, but it is not so simple as it looks like, because the ball has to be predicted in future in a manner that the ball and the robot are reaching the position at the same time. The ball prediction uses the model of linear regression and if the position function is only calculated and the commands are not sent via radio to the robot, the developed position function delivers a time (how long is the duration of reaching a certain point). With an approximation function it is possible to adjust this point in future, so that the robot can hit the ball. We call it 'virtual concept', because some calculation are done by the host computer and are not executed by the robots. The best solution of the approximation function will be sent to the robots. The team lineup is responsible for assigning each robot its task. This can be done via fuzzy sets, distance or minimal time. For the Mirosot League it is sufficient that the robot with the minimal distance is the attacking one and the defenders, especially the goalie are fix assigned (Würzl, 2005).

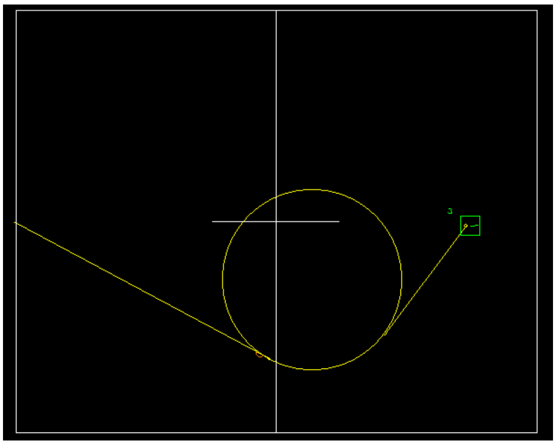


Fig. 4: Screenshot of an attack-kick

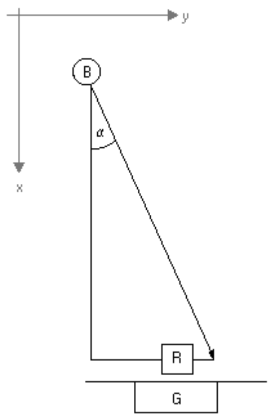


Fig. 5: Goalie

The goalie of the IHRT-system is a simple calculation. The x-line is always the same and the calculation of the y-position is a simple calculation of tangens. The predicition in the case of the goalie is different, because the goalie uses not the previously ballprediction discussed(linear regression), but only a simple calculated value for its position correction. Fig. 5 shows the objects whereas the formulas are:

$$R.x = 5$$

$$R.y = B.y - \tan(\alpha) * (B.x - R.x)$$

$$R.\chi = 90$$

6. 11 VS. 11

11 vs. 11 replaces 7 vs. 7. Fig. 6 shows the 7 vs. 7 playground. The dimension of the 7 vs. 7 playground

is 2.80 m times 2.20 m and goal size is 0.6 m. The new 11 vs. 11 playground has a dimension of 4.40 m times 2.80 m. The goal size is the same. The biggest disadvantage of the new playground is that there is loss of pixels in the width, because of the length of the new playground.

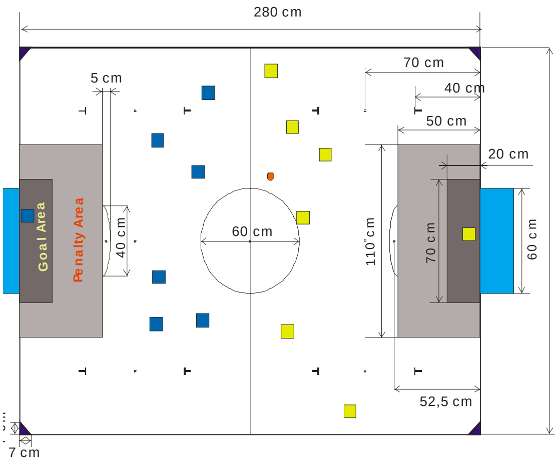


Fig. 6: 7vs. 7 playground

At the worldcup 2004 in Korea, the task of Mirosot will be fulfilled, because there will be the first matches 11 against 11 robots (Würzl, 2005). The playground size is 4,40 m times 2,80 m. Therefore 2 cameras have to be used. It is a very hard task to realise the cycling time of 20 ms, but with the fast digital cameras, which are used by the division of intelligent handling and robotics, this is not the biggest problem. The problem is the computing power. At the moment a Siemens Workstation with a P4 2,66 GHz and 512 MbRam is used, but for the HLS colour system, the computing power is not sufficient, especially the access to the memory is too slow. The RGB model works without any problem, but the RGB model is not so well suited for the task of robot soccer, because the vision system of a robot soccer team heavily depends on the lighting conditions. Hard tasks to realise 11 vs. 11:

- calculate the deformation out of the picture. It is different from the old algorithm, because the camera has turned by 90 degrees (other dimensions of the playground) (Fig. 7).
- in the middle of the playground the two cameras see the same area
- the detection of 10 different colours (ball, home colour, opponent colour, 4 main colours and 3 additional colours). Therefore tracking (with 1 colour or 2 colours) was realised, but it is better for the precision of the system to use more colours (Fig. 8).
- for each camera it is necessary to have its own colour model (RGB, HLS) and boundary setting

Fig. 7: Screenshot of the Protoype-System (11 vs. 11) (Würzl, 2005)

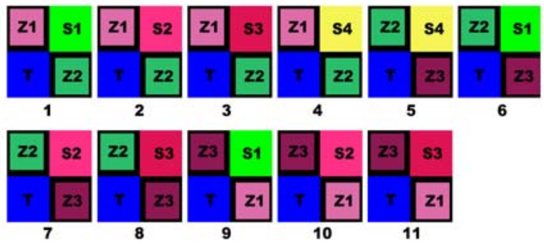


Fig. 8: colours for 11 vs. 11 (Putz, 2004; Würzl, 2003)

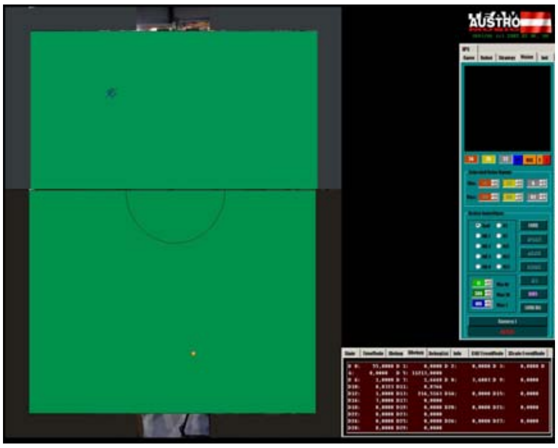


Fig. 9: Screenshot of the Prototype-11 vs. 11-System (Würzl, 2005)

At Fig. 9 you can see the detected ball and 1 robot.

The main advantage of the IHRT-Visionsystem is that only one host computer with 2 framegrabbers is used.

7. PARADE

For dancing robots another strategy was developed. The system of the division of intelligent handling and robotics is able to control up to 11 robots.

The movements of the robots are not random, but coordinated. That means if one robot is leaving its given trajectory the dancing partner (robot) waits for the other robot.

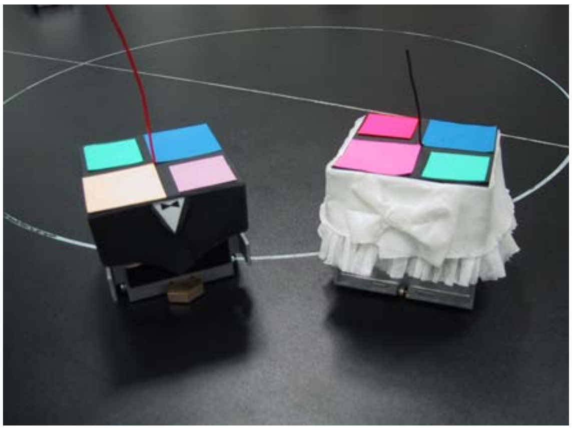


Fig. 10: dancing robots

The programming could be done even by students with no programming experience, because it is performed in an excelsheet. The programming style reminds to that of programming NC-machines (call different functions with different parameters which are executed sequential).
There are 5 different functions:

- ParadeWait: The robot waits a certain amount of time given in milliseconds.
- ParadePosition: The robot goes to a specified point.
- ParadeRotate: The robot tries to reach a certain angle in the absolute coordinate system.
- ParadeCircle: The robot moves along a given circle.
- ParadeTimeRotate: The robot rotates for a specified time.

If robot 1 should wait for 500 ms and waits for robot 2 to finish its event, the line in the excelsheet looks like the following:

F	P1	P2	P3	P4	P5	S1	S2	...
1	500						1	

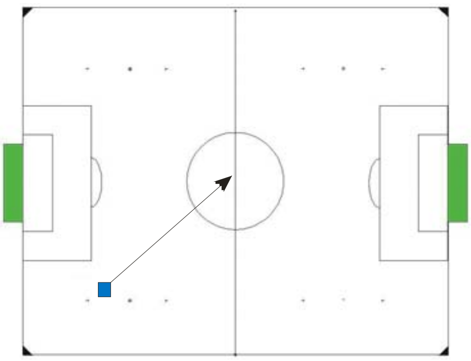


Fig. 11: ParadePosition (Würzl, 2005)

In this example (Fig. 11) robot 1 should go to the middle point of the 7 vs. 7-playground with the maximum velocity of 100 cm/s.

F	P1	P2	P3	P4	P5	S1	S2	...
2	140	100	0	100				

An example for ParadeRotate is shown in Fig. 12. (the robot tries to reach an angle of 0 degrees):

F	P1	P2	P3	P4	P5	S1	S2	...
3	0							

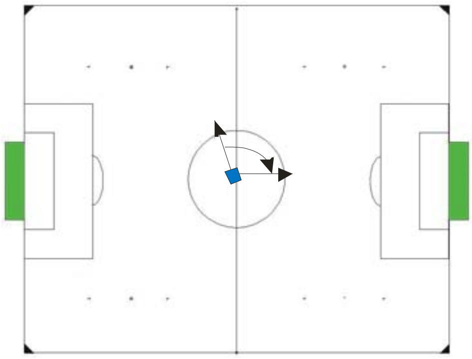
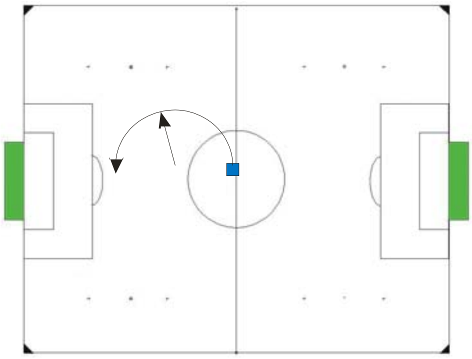


Fig. 12: ParadeRotate (Würzl, 2005)

Another example (Fig. 13) is the command for moving along a given circle (the robot makes a semicircular movement with a radius of 20 cm at a velocity of 10 cm/s (180 degrees)):

F	P1	P2	P3	P4	P5	S1	S2	...
4	10	20	180				1	

Fig. 13: ParadeCircle (Würzl, 2005)



If robot 1 should rotate for 500 ms with a angular velocity of 720 degrees/s. (Fig. 14):

F	P1	P2	P3	P4	P5	S1	S2	...
5	500	720	1					

After all robots have their reasonable command sequences specified, the excel file is translated into a binaryfile and the IHRT-Hardware Multi Agent System executes these commands.

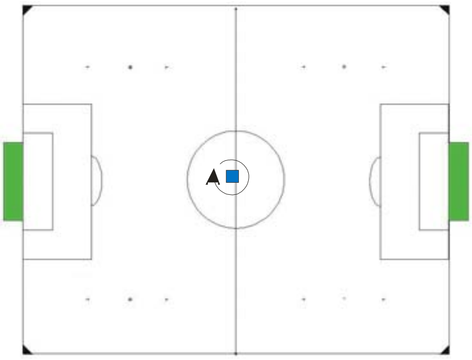


Fig. 14: ParadeTimeRotate (Würzl, 2005)

Fig. 15: Simulation of parades (Würzl, 2005)

Furthermore these functions were realised in the 5 vs. 5 Simurosot program. If you are interested in the source code, please contact the division of intelligent handling and robotics. Fig. 15 shows a screenshot of the simulator.

8. SUMMARY AND OUTLOOK

To increase the computing power a small microprocessor (DSP) will be added to the minirobot (Schierer, 2004).

By the use of the computing power and the multimedia functions of such a small module, it is no problem to integrate more sophisticated strategies or more sensors like a small camera, a compass, etc. This effort is useful to make the robot more autonomous and increase its “intelligence”. It is our opinion that this is the right step into the future, because the problem of vision based Hardware MAS is actually solved.

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