Proceedings of the 17th World Congress
The International Federation of Automatic Control
Seoul, Korea, July 6-11, 2008

ROBOTSOCCER

Peter Kopacek

Intelligent Handling and Robotics (IHRT),Vienna University of Technology
Favoritenstr. 9-11, A-1040 Vienna, Austria
kopacek@ihrt.tuwien.ac.at

Abstract: Robot soccer was introduced with the purpose to develop intelligent cooperative multi-robot (agents) systems (MAS). From the scientific point of view a soccer robot is an intelligent, autonomous agent, carrying out tasks together with other agents in a cooperative, coordinated and communicative way. Robot soccer provides a good opportunity to implement and test MAS algorithms for current and future industrial applications. Generally robot soccer is a good test bed for the development of MAS. The robots in a team have a common goal – to kick the ball in the opponent goal and to avoid goals against the own team. The cooperation and coordination of actions by means of communication are necessary. In this paper the development of three generations of mini robots for robot soccer, in the FIRA categories Miro- and Narosot, are described. Finally some industrial applications as a "spin-off" of robot soccer are shortly presented.

1. INTRODUCTION

There is a new term "edutainment". It is composed from two terms – education and entertainment. The aim of edutainment is to make transparent "High Tech" for a broader public. There is an approach to bring kids the difficult scientific matters in the way of edutainment using soccer playing robots.

In 1999 the first Robot Olympiad (www.iroc.org) was held in Korea. This was a national event, but the organizers made this event international. The participating teams were selected from elementary and high schools and got robot kits.

Furthermore robot soccer was introduced to develop intelligent cooperative multi-robot (agents)-system (MAS). From the scientific viewpoint a soccer robot is an intelligent autonomous agent, which carries out tasks with other agents in a cooperative, coordinated and communicative way. Generally robot soccer is a good test bed for the development of MAS. Furthermore it is also a good tool for spending free time for education and leisure. (Han and Kopacek, 1998)

Future production systems will become more and more complex. Several autonomous, intelligent, mobile robots are working together in a cooperative way. In order to avoid conflict situations and delays and guarantee a smooth movement, robots should have the capability to communicate and to cooperate in order to coordinate their actions.

Soccer is one of world wide well-known sport. It is exciting to watch how robots play the game. It is also possible not only to watch the game but also to play the game - human against computer, human against human - using joystick as well as keyboard. The big question for common use is the price of whole system. With the development of electronic peripheral devices the costs are going down. For the realization of interdisciplinary research works should be done including following areas, like robotics, image processing, sensors, mechatronics, communication etc.

At the moment there are worldwide two robot soccer organizations, FIRA (Federation of International Robot-soccer Association, www.fira.net) and RoboCup (www.robocup.org). The objectives and scope of both organizations are similar. The size of the robots and the playground, numbers of playing robots are different.

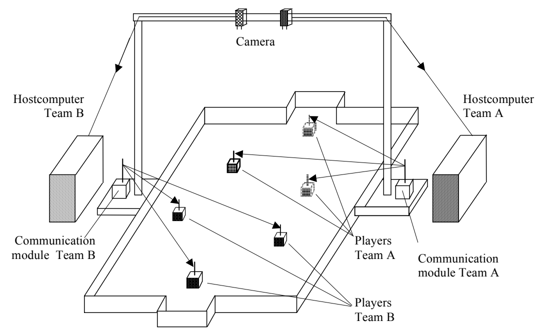


Fig. 1. Overall system of robot soccer (Würzl, 2005)

In this contribution the rapid development of robot soccer in FIRA (Federation International of Robot Soccer Association), especially in the categories Miro and Narosot will be described.

The system (FIRA Mirosot) works as follows (Fig.1): A camera approximately 2m over the playground delivers minimum 120 pictures/second to the host computer. With information from colour patches on top of the robots, the vision software calculates the position, orientation, speed and acceleration of the robots and the ball. With this information the host computer calculates motion commands according to the implemented game strategy and sends them wireless to the robots. At our institute 3 generations of soccer robots "Roby Go", "Roby-Run" and "Roby-Speed" - Team AUSTRO from Vienna University of Technology - were developed (Kopacek, 2006).

978-1-1234-7890-2/08/$20.00 © 2008 IFAC

10.3182/20080706-5-KR-1001.1177

This progress was driven mostly by the new developments in hardware (precision mechanics, information technology – computer power, electronics, …..) and software (programming, AI, ………).

2. PAST

In 1995 robot soccer was introduced in Korea. In 1995 and 1996 there were competitions for Micro-robots.

Already two **MI**cro-**Ro**bot **SO**ccer **T**ournaments (MIROSOT 96, MIROSOT 97) were organized by FIRA (Federation of International Robot-soccer Association) in Korea. In 1998 the Micro-Robot World Cup Soccer Tournament took place in Paris in conjunction with the FIFA World Cup 1998. Over 50 teams participated in MIROSOT '98.

In Europe first demonstration games were organised at Vienna University of Technology in September 1997 and the first FIRA European Cup took place on April 25 and 26, 1998 in Vienna. 4 teams from Korea, Switzerland, Spain and Austria attended this competition. (Kopacek, 2006)

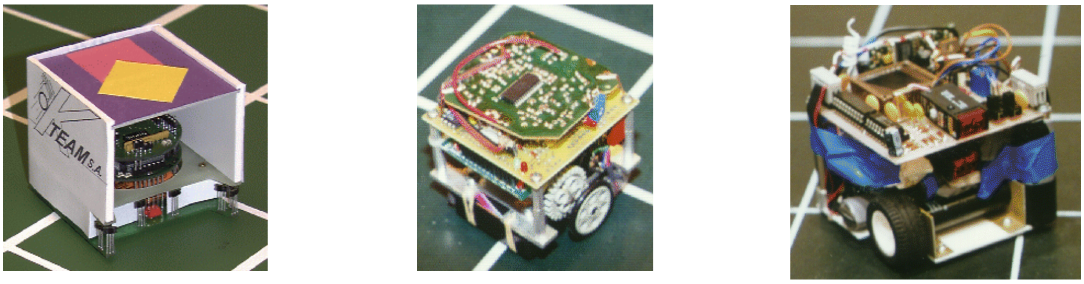
At that time the robots were very slow (approx. 7 km/h) with a low acceleration (3m/s²). The games were 3 vs. 3 on a playground of 1.5m x 1.2m. The image processing system was completely analogue and transmitted only 30 frames/sec.

Until 1999 the Team AUSTRO from Vienna University of Technology played with robots from Korea. For the technical details see Table 1. In 1999 the development of our first soccer robot "Roby Go" was initiated.

"Roby Go" is a two wheel driven minirobot, distinguished by his simple, compact and modular construction. It has two PWM controlled DC motors and can not only be used as a soccer robot in the category Mirosot, but also as a reasonable cheap test bed for Multi Agent Systems.

The heart of the robot, the microcontroller C167 can be programmed by the serial port and has a CAN bus interface. Therefore it is possible to connect several microcontroller boards for different tasks. Additional sensors can be easily attached in the future. The electronic part has a modular and open architecture and consists of two boards one board is responsible for power electronic and one for communication. The control software is designed based on open architecture.

In 2002 "Roby Run" was ready for application. The difference to "Roby Go" was an improved mechanical construction, a miniaturized electronics together with a more powerful microcontroller. These improved the speed and the acceleration as well as the robustness of the robot.



The STeam Engines (CH) Newton (USA) ROGI II(E)

Fig. 2. MiroSot Robots from 1998

Table 1 Comparison of selected robot soccer teams participating European Cup 1998

Team	**ROGI II (Spain)**	**The STeam Engines (Switzerland)**	**AUSTRO (Austria)**
Microcontroller	87C552	Intel µ-controller 80c562	AT89C52
Communication module (MHz)	RF Frequency: 433 or 492 MHz	RF frequency : 418 or 433 MHz	RF frequency : 418 or 433MHz
Motion controller and motors	Motion controller (L293) Encoder : 16 pulses per Rev. MAXON DC Motor 1.5W Velocity : 12.300 rpm, reduction ratio (16 :1).	Motion controllers: Direct Vision System 2 motors (one motor per wheel) max. speed: 2 m/s	Motion controller (LM629) two wheeled vehicle (two DC motors and encoders) max. speed : 1.2m/sec
Extra sensors	ball and obstacle sensor		
Power	9 batteries * 1.2V		8 batteries * 1.2V
Main computer		Pentium Pro 200 MHz OS : Windows NT	Pentium II 300 MHz OS : Windows 95

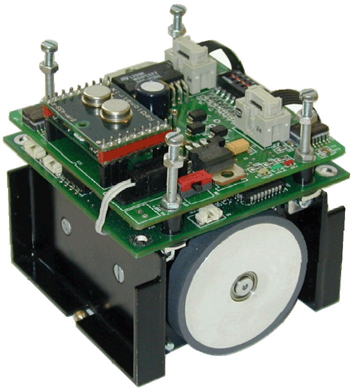


Fig. 3. Roby-Go

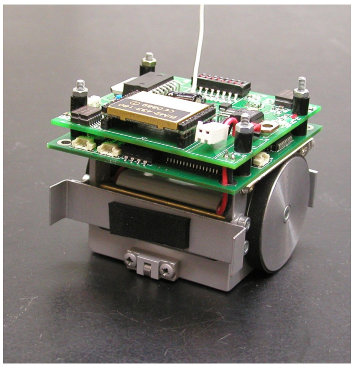


Fig. 4. The mobile mini robot " Roby Run "

3. PRESENT

At the moment five, seven or eleven robots build a team. The dimensions of the related playgrounds are: 180 x 120cm; 240 x 180cm and 400 x 280cm. For the largest playground most of the teams are using two cameras with up to 200 frames/second.

This is necessary because the speed and acceleration of the robots increase dramatically in the last two years (Tab.2). For example "Roby Speed" (Fig. 5a) have a maximum speed of 24km/h with an acceleration of $10m/s^2$. Further improvements to "Roby Speed" are:

- robust and compact mechanical design
- miniaturized electronics: the two PCB`s (7.4 x 7.4cm) are now reduced to one (3.2 x 3.2 cm) and fully integrated in the body.

For special applications a smaller robot with the dimensions 4 x 4 x 5cm, "Roby Naro" (Fig. 5b), was developed (Putz, 2004). Sometimes a robot has to reach positions in a very "narrow" environment. In addition he is playing soccer in the category "NaroSot".

One of the latest developments is the extended (e-) middle league: 5 vs. 5 robots on a playground of 7 vs. 7 (220 x 180cm).

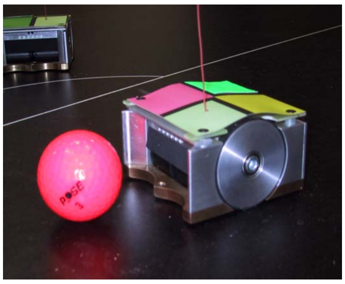


Fig. 5a. Roby Speed

Fig. 5b. Roby Naro

4. FUTURE

Following problems should be solved for further development:

- Communication between agents: At the moment the communication is working in one-direction, i.e. the host computer sends commands to the robots. For the cooperation between agents, bi-directional communication is necessary. When the number of agents increases, there are problems on the usable number of channels and protocols.
- Intelligent behaviour of robots: Implementing intelligence not only in a single robot but also in a group behaviour.
- Improving vision system: A soccer robot can move with maximum speed approximately 6m/s and the ball faster. The vision-system can loose the position of robots and balls.
- Prediction algorithm: Because of time delay it is necessary to implement prediction algorithms of future locations of the ball and the robots

Next developments will be towards humanoid robot soccer players. There is a category HuroSot (Humanoid Robot-soccer tournament) in FIRA. The robots are reasonable cheap – so called "amateur" robots. On the other hand several "professional" humanoid robots are developed, like ASIMO (Honda), Qrio (Sony)……. More and more producers are offering robots with 2 legs to a relatively high price. Therefore it will be necessary to develop humanoid robot soccer players just between these two categories

Table 2. Specifications of the IHRT – robots

	Roby Go	**Roby Run**	**Roby Speed**
Microcontroller	C167 (Infineon)	C167 (Infineon)	XC167 (Infineon)
Communication Module	RF frequency : 418 or 433 MHz	RF frequency : 418,433 or 869 MHz	RF frequency : 418,433, 869 or 914 MHz
Software Controller	PID, Neuro PID or advanced algorithms Sampling Time 1 ms	PID, Neuro PID or advanced algorithms Sampling Time 1 ms	PID, Neuro PID or advanced algorithms Sampling Time 1 ms
Dimensions in mm (Lengthx Widthx Height)	75 x 75 x 75	75 x 75 x 75	75 x 75 x 46
Motors	Faulhaber 2224 06 SR, 4.5 W	Faulhaber 2224 06 SR, 4.5 W	Faulhaber 2224 06 SR, 4.5 W
Sensors		Acceleration sensor	Acceleration sensor
Power	NiMH 9 Cells, 1.2V, 550mAh	NiMH 9 Cells, 1.2V, 700mAh	LiIo 11.1V 1400 mAh
Max. Speed (m/s)	2.54	3	3.9
Max. Acceleration (m/s^2)	2.54	6	10
Main Computer	Pentium IV 1.5 GHz OS: Windows 98	Pentium IV 2.8 GHz OS: Windows 2000	Centrino 2.26 GHz OS: Windows XP
Vision System	Analogue, 60 half pictures / s	Digital, 60 full pictures / s	Digital, 200 full pictures / s

We are currently working on a humanoid, two legged robot called **ARCHIE.** The goal is to build up a humanoid robot, which can simulate in some situations a human being. Therefore Archie needs a head, a torso, two arms, two hands and two legs and will have the following features:

1. Height: 120 cm
2. Weight: less than 40kg
3. Operation time: minimum 2hrs
4. Walking speed: minimum 1m/s
5. Degrees of freedom minimum 24
6. "On board" intelligence.
7. Hands with three fingers (one fixed, two with three DOFs)`.
8. Capable to cooperate with other robots to form a humanoid Multi Agent System (MAS) or a "Robot Swarm".
9. Reasonable low selling price – using commercially available standard components.

Sensors: Proximity for measuring distances and to create primitive maps, temperature, acceleration, pressure and force for feeling and social behaviour, two CMOS-camera-modules

Table 3. Robot Soccer modules and their use for selected industrial projects

Robot Soccer
Roby Speed, Roby Naro

	Selected Projects \ Hard- and Software parts		Mech. Constr	Electronics	Power supply	Drives	On board Computer: Control	On board Computer: Path planning	Sensors	Image Proce.	Stragetgy	Communication	MAS
Stationary	Disassembly Cell for PCB's									●		◖	
Stationary	Disassembly cells for mobile phone								◖	●		◖	
Mobile	Parquet floor grinding robot [1]						●	●			◖		
Mobile	HUDEM	Aurold[1]					●	●	◖				◖
Mobile	HUDEM	Pioneer[1]					●	●				◖	
Mobile	Roby Space		●	●	●	●	●	◖	◖	◖		●	◖
Mobile	Archie		◖	◖	◖	◖		◖	◖	◖		◖	◖

[1] Based on commericially available mobile platforms; ●…..Completely used (70 – 100%); ◖…….Partially used (30-70%)

for stereoscopic looking, two small microphones for stereoscopic hearing and one loud speaker to communicate with humans in natural language.

5. INDUSTRIAL APPLICATIONS

We started with robot soccer in 1996 and have now some experiences. For us is robot soccer a reasonable cheap testbed for industrial applications. Therefore we transferred some parts of our soft- and hardware into industrial projects collected in Tab.3.

As a "spin off" of robot soccer some industrial applications like semiautomated disassembly cells, "Woody" a parquet floor grinding robot, robots for humanitarian demining (Aurold, Humi), minirobots for space - Roby Space (Kopacek et. Al, 2004), (Han, 2005) - and a humanoid robot (Archie) are realised or in realisation. (Kopacek, 2007).

For example the wireless communication developed for the robot soccer system is partially used in for connecting several disassembly cells on different places. The transfer of software modules from robot soccer to the selected applications, listed in Tab.3, require some adaptions. In most of the cases the modules work very satisfactory. Because of the sensitivity of the soccer system problems arise usually by the industrial environment. On the other hand if we transfer industrial modules our soccer system get more and more robust.

6. CONCLUSION

In this paper the development of a family of mobile mini (naro) robot is described. The team AUSTRO won with these robots some categories in FIRA World Cups as well as European Cups.

Especially in Narosot only few teams can participate in the competition. A problem was the stability of the Narorobots. They can only move with a reduced speed.

Future works are the improvement of the intelligent and autonomous behaviour by means of adding visual sensors and the realization of full communication between robots to carry out their tasks in coordinated as well as cooperative ways. Furthermore the final goal of robot soccer is to play with 11 humanoid robots (e.g. Archie) again a real human soccer team.

Finally industrial applications as a spin off of robot soccer are listed. Further projects are in progress.

7. LITERATURE

Han, M.-W.; Kopacek, P. (1998): Intelligent Autonomous Agents – Robot Soccer. In: *Proceedings of the 7th Int. Workshop on "Robotics in Alpe-Adria-Danube-Region RAAD'98"*, Smolenice Castle, Slovakia, p. 261-266.

Han, M.W. (2006): Mobile Mini-Robots for Space Application, Climbing and Walking Robots, *Proceedings of the 8th International Conference on "Climbing and walking robots and the Support Technologies for Mobile Machines (CLAWAR 2005)"*, p. 1037- 1044.

Kopacek, P., M. Han, B. Putz, E. Schierer, M. Würzl (2004): A concept of a high-tech mobile minirobot for outer space; in: *ESA SP-567 Abstracts of the International Conference on "Solar Power from Space SPS'04",* Granada, Spain, p. 132 - 133.

Kopacek, P., M.-W. Han, B. Putz, E. Schierer and M. Würzl (2006): Narosot – Nanotechnology in Robot Soccer. *Preprints of the" Conference on Information Systems, Control and Interoperability, INCOM 2006",* Saint-Etienne, France, p. 193 – 198.

Kopacek, P. (2006). Robotsoccer; Past, Present and Future. *Proceedings of ISR 2006,* Munich, Germany, p.153

Kopacek, P. (2007): Industrial and commercial applications of mobile mini robots. *Proceedings of the IFAC Symposium "Cost Oriented Automation – COA07",* La Habana, Cuba, p.11-18

Putz, B. (2004): Development of the new Soccer Robots "Roby-Speed" and "Roby-Naro". In: *Proceedings of CLAWAR/EURON/IARP Workshop on "Robots in Entertainment, Leisure and Hobby, ELH '04"*, Vienna, Austria, p. 47 – 52.

Würzl, M. (2005): "A contribution to robotics especially in the field of expert- and multi agent systems", *PhD thesis, Intelligent Handling and Robotics,* Vienna University of Technology, 2005 (in German).