Robotino – An Open Learning Mobile Robot System for Robocup

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Abstract. This paper describes a proposal for a new competition in Robocup. The idea is to play a kind of indoor ice hockey only using a rather simple equipment. The goal is to provide a prepared robot platform Robotino in order to avoid too much effort in the technical equipment instead of focusing on the development of artificial intelligence methods. The technical structure and the open software interface of the robot system will be explained. At the end we will point out the concept of a demonstration competition in order to analyze the proposed concept for the future.

1 Introduction

The approach of this paper is to suggest a new competition as preparation of the Middle Size league. One of the goals of the Robocup is to encourage young research teams to develop new creative implementations of artificial intelligence methods to apply and demonstrate them in the framework of Robocup. However, the investment in the hardware and electronic technology for the robot systems in the Middle Size League has been extremely grown up in the last years. Thus it is very difficult to attract new groups because now the first investment is too high to apply for this kind of competition.

The proposed concept is very easy. Use a ready to start with robot platform and create game rules which avoid the necessary of developing new technical equipment but focus on the main goal to use the robot systems as a great platform to demonstrate new developments in artificial intelligence.

We will first describe the general rules of the game. Secondly, we describe the robot platform and its open interface to do further development. Finally we explain the first step in terms of a demonstration competition during the Robocup 2009.

2 Hockey Challenge Cup

The goal of the game is to play hockey. Each robot has the same fixed device to hit a puck.

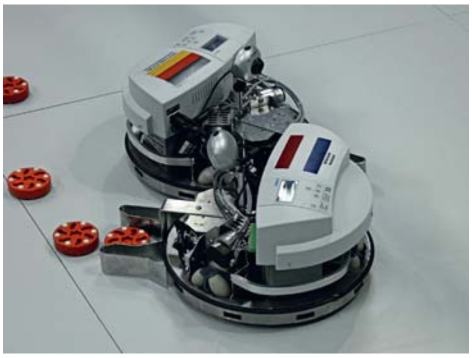

Fig. 1. This figure shows the device to push a puck and to hit the puck with the sides.

The dimensions of the robots are bounded by a cylinder with radius 0.4 m and height 0.3 m. The pucks are circular disks of red color with diameter 10 cm. The competition arena consists of a field of 4.5 m x 4.5 m. The field is bounded by boards having a height of 0.5 m which makes sure that cameras of the robots are not interfered by objects outside of the arena. The field is divided by 5 lines. There is a black line dividing the field into two halves.

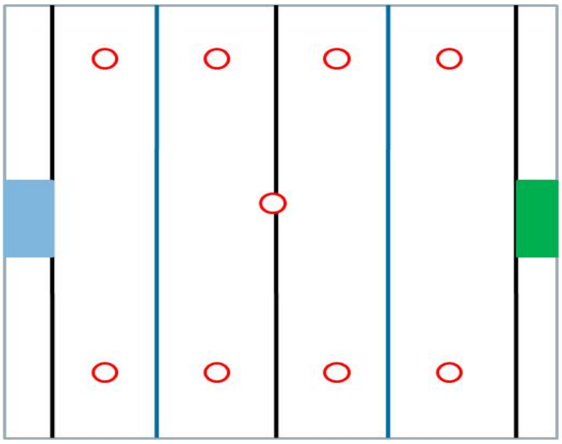

Fig. 2. This figure shows the division of the field by five lines, two goals, one kick-off point and 8 bully-off points.

- The kick-off point for a game is in the center of this line. This center point is marked by a black circular disk with diameter of 15 cm.

- Near the end of each half there is a black line parallel to the center line. This line is called the **goal line**. The distance to the end is 25 cm.

- All black lines have a width of 38 mm.

- There is a goal touching the goal line in the center. The goal area is marked green or blue at the side walls. The width of the goal is 80 cm. The goal is terminated at the sides by small profiles so that no pucks being behind the goal line can be pushed in the goal area.

- In front of the goals there are half circles of radius = 40 cm. These circle lines consist of metallic stripes which can be detected by inductive sensors.

- There are two additional blue lines dividing the field in three equal parts – one attacking area and two defensive areas. These lines are in fact metallic stripes (silver color) which can be detected by inductive sensors.

- The width if the metallic stripes will be 50 mm.

- There are 4 bully-off points in the attacking area and 4 bully-off points in the two defensive areas. The bully points will be marked by black circular disks of 10 cm diameter.

2.1 Rules

The rules follow the regulations of the IHF (International Ice-Hockey Federation) but are simplified. The regulations are divided into following sections:

- Game rules
- Players and equipment
- Teams
- Playfield
- Penalties
- Additional rules

Each match is controlled by a referee who has full authority to enforce the rules of the game in connection with the match to which he has been appointed. A referee may have assistant referees. At least one hour before the match will be started it will be decided which goal is assigned to a team.

The regular playing time of a match is divided into three thirds à 10 minutes. After each third there is a break of 5 minutes. The playing time will be stopped at the end of a third or because of an irregularity pointed out by the referee. The playing time will be continued if the referee again starts the game. Thus the actual time of a game may last for more than 40 minutes.

A goal will be only scored if following is fulfilled:

- The puck has completely crossed the goal line and is inside the goal area.
- The last player who has touched the puck must be in the defensive area of the corresponding goal. This enforces the players to work in a team which we mainly want to demonstrate.

A game will be started resp. restarted

- at the beginning of each third
- or after a goal

The start will be done at the kick-off point.

- All team members must be in her downfield in front of their defensive line.
- The referee places the puck on the kick-off point. Only one player of a team is allowed to be nearby in order to catch the puck.
- At the first start of the game it will be the team which got the right to start at the kick-off point by lottery.
- After each third of the game the right to start at the kick-off point will be changed. No change of the direction to play!
- After scoring a goal, the non successful team receives the right to start at the kick-off point.

Otherwise the referee will start the game at one of the bully-off points:

- The referee places the puck on one of the bully-off points. Then only one player of each team is allowed to be nearby in order to catch the puck. The other team members must be in their downfield at least one meter away from the bully-off point.

Offside rule:

- An attacking player is in the defensive area of the opponent team before the puck has completely crossed the blue defensive line, then the player is offside.
  Note: The attacking player is in the defensive area of the opponent if he is between goal and defensive line and no part of the robot is touching the defensive line.
- The referee will stop the game and will restart the game with at the next bully-off point outside the defensive area.

Goalkeeper:

- There is no goalkeeper.

- All players have the same task to hit goals or to avoid goals of the opponent team.
- However it is only allowed to have only one team member in her own defensive area. Otherwise the referee will stop the game and give a penalty shooting, see 2.3, for the opponent team.
  Note: A robot is in its defensive area if the system is between own goal area and the defensive line and no part of the robot is touching the line.

Other Irregularities:
- If the boundary of a goal is displaced then the game will be interrupted and will be restarted at a bully-off point next to the goal. The referee can give a penalty shooting against the team, see 2.3, the robot being obviously responsible for this attack.
- If the puck cannot be moved for a certain time, the referee will interrupt the game and restart it at the next bully-off point.
- If after a stop sign, see 2.2, of the referee one of the robots is still moving then there will be a penalty shooting against its team.
- If one player pushes a player of the opponent team to force him in a non regular position then the referee will stop the game and there will a penalty shooting against his team.

2.2 Teams and Players

A match is played by two teams, each consisting of not more than 3 players. A match may not start if either team has no players.
- Robots of the same team will be marked by a colored shirt above the controller housing. The shirts have three equal stripes of color either green – white – green or blue – white – blue depending on the color of their goal.

- Each player is a mobile robot system of type Robotino®, see figure 1, with the same device to hold and to hit the puck. The challenge is to learn how to catch the puck, to hold the puck, to pass or to hit the puck and keeping the knowledge of the orientation. Teaching the robot to handle efficiently a combination of these different skills makes the game really exciting and challenging for programming.

- The robots are remote controlled via WLAN by programs running on a PC. If the game is running no participant is allowed to do any changes of the PC program. The referee is the only authority deciding to start, to stop or to interrupt the game. The referee will create a stop or interruption by disconnecting the WLAN communication between PC and the mobile robot systems.

- If the game will be started or restarted, then the participants have the possibility to start their program(s) by one (!!) click on a PC key button.

- If one player is not working during the match then the referee will interrupt the match. The player must leave the arena. The match will be restarted at the bully-off point next to the puck. The player can only be set back in the match at the earliest after two minutes. This can only happen if the referee will interrupt the game and restart it at the bully-off point next to the puck.

2.3 Penalties

A penalty shooting will be done as follows:

- First, it will be decided which team will do the penalty shooting. This team is called the attacking team.
- One player of the attacking team will be selected to perform the penalty shot.
- One player of the defensive team will be selected as goalkeeper.
- The player of the attacking team starts moving with the puck at the kick-off point if the referee releases the penalty shot. The player has only one chance to hit the puck in the goal.
- The goalkeeper can try to stop the attacking player but no wheel of the robot is allowed to cross the front line of the goal.

A **Penalty Shootout** will be done as follows:

- Each team must select one player to be the goalkeeper.
- Each team gets the right for three penalty shootings. After each penalty shooting the role of the attacking team will be changed.
- By lottery it will be decided which team will first start with the penalty shooting.
- The penalty shooting will be always done on the goal being assigned to the opponent team.
- If the number of scored goals is still equal then this penalty shooting will be continued until one team scores and the other not.

2.4 Programming

Programming can be done in C, C++, C#, Java or using Robotino View, see chapter 3.4.1. Each team is responsible for the compiler of corresponding programming language.

3 The Mobile Robot System

The mobile robot system Robotino® is a platform with an open mechanical interface for the integration of additional mechanical devices and an open electrical interface to integrate easily additional sensors or motors of devices. Power is supplied via two 12 [V] lead gel batteries which permit a running time of up to two hours. The scope of delivery likewise includes a charging device.

Fig. 3. Image of Robotino® of Festo Didactic GmbH & Co.KG

Robotino® is driven by 3 independent, omnidirectional drive units. They are mounted at an angle of 120° to each other. The three omnidirectional drive units of Robotino®, defines the robot as being holonomic, meaning that the controllable degrees of freedom equals the total degrees of freedom of the robot. The drive units are integrated in a sturdy, laser welded steel chassis. The chassis is protected by a rubber bumper with integrated switching sensor.

Robot dimensions:

- Diameter: 370 mm
- Height including housing: 210 mm
- Overall weight: approx. 11 kg
- Maximal payload of about 6 kg

3.1 Drive Unit

Each of the 3 drive units consists of the following components:

- DC Dunker motor with nominal speed of 3600 rpm and nominal torque of 3.8 Ncm.
- Integrated planetary gear unit with a gear ratio of 4:1.

- Omnidirectional wheels of diameter of 80 mm.
- Toothed belt with gear wheels providing a transmission ratio of 4:1.
  Altogether this provides a gear transmission ratio of 16:1.
- Incremental encoder with a resolution of 2048 increments per motor rotation.

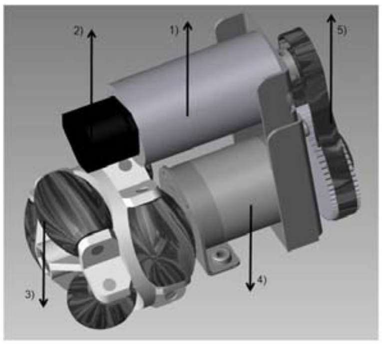

Fig. 4. Drive unit with motor (1), encoder (2), omnidirectional wheel (3), planetary gear (4), toothed belt (5)

The motor speed will be controlled via a PID controller implemented on a Atmel microprocessor of the controller board of Robotino®.

Omnidirectional wheels are all based on the same general principle: while the wheel proper provides traction in nthe direction normal to the motor axis, the wheel can slide frictionless in the motor axis direction. In order to achieve this, the wheel is built using smaller wheels attached along the periphery of the main wheel, see Fig. 4.

3.2 Sensors

Robotino® is equipped with 9 infrared distance measuring sensors which are mounted in the chassis at an angle of 40° to one another. Robotino® can scrutinise all surrounding areas for objects with these sensors. Each of the sensors can be queried individually via the controller board. Obstacles can thus be avoided, clearances can be maintained and bearings can be taken on a selected target.

The sensors are capable of accurate or relative distance measurements to objects at distances of 4 to 30 cm. Sensor connection is especially simple including just one analogue output signal and supply power. The sensors' evaluation electronics determines distance and read it out as an analogue signal.

The anti-collision sensor is comprised of a switching strip which is secured around the entire circumference of the chassis. A switching chamber is located inside a plastic profile. 2 conductive surfaces are situated inside the chamber, between which a given clearance is maintained. These surfaces are short circuited when even minimal pressure is applied to the strip.

A reliably recognisable signal is thus transmitted to the controller unit. Collisions with objects at any point on the housing are detected and, for example, Robotino® is brought to a standstill.

The inductive proximity sensor is supplied as an additional component. It serves to detect metallic objects on the floor and is used for continuous-path control, e.g. it might be used to detect the blue lines (metallic stripes) on hockey field. It reads out signals of varying strength depending upon whether it is located in the middle or at the edge of the metal strip. Path tracking can thus be controlled in a differentiated fashion.

The inductive proximity sensor must be attached to the mounting furnished for this purpose, and must be connected to the I/O interface. The output voltage is 0 to 10 [V]. The sensing range is 0 to 6 mm.

Path tracking can also be implemented with the two included diffuse sensors.
Flexible fibre-optic cables are connected to a fibre-optics unit which works with visible red light. Reflected light is detected. Different surfaces and colours produce different degrees of reflection. However, gradual differences in reflected light cannot be detected. The sensors must be attached to the mountings furnished for this purpose, and must be connected to the I/O interface.

Robotino® is equipped with a color webcam. The webcam is equipped with a USB interface and provides an integrated jpeg compression. It supports a colour depth of 24 bit true colour and a VGA resolution with 15fps. The reason for jpeg compression is that image processing can be done on an external PC via WLAN connection.

3.3 Controller Board

The controller housing is connected to the wiring in the chassis via one plug-in. Thus you can easily take off the controller housing and you have direct access to the mechanical system.
The controller system of Robotino® is divided into two parts – an embedded PC and a microcontroller interface card:

Fig. 5. Controller of Robotino® consists of an embedded PC and a microcontroller interface board.

The interface card consists of four Atmel microprocessors which provide a PID controller for the three motors. Further they can provide the control for another motor. The interface card communicates via a serial interface with the embedded PC. Also the microprocessors send and read the integrated sensor signals. The interface card also provides an open I/O interface to connect additional sensors and actuators:

- 10 analogous inputs 0 -10 [V], 50 Hz
- 8 digital in- and outputs (24 [V], short-circuit-proof)
- 2 relays for additional actuators

For example, localization and mapping methods need an additional range sensor – laser scanner – as described in the paper [xx].

The main controller is the embedded PC 104 plus controller with the 800 MHz processor AMD LX800. The PC has a SDRAM of 128 MB and is provided with a 1 GB flash card. There are numerous communication interfaces on board:

- 2 x Ethernet
- 2 x USB
- 2 x RS232
- Parallel port and VGA port
- Wireless LAN Access Point following the standards 802.11.g and 802.11.b. The access point can be switched into a client mode. As an option you may use WPA2- coding.

3.4 Software

There is a Linux operating system with real time kernel running on the embedded PC 104. The main part of the controller is the Robotino® server, a real time Linux application. It controls the drive units and provides interfaces to communicate with external PC applications via W-LAN. There is an API with libraries which allow to create applications for Robotino® in numerous programming languages:

- C++ und C
- C#
- .net and JAVA
- MatLab and Simulink
- Labview

You may find a lot of examples concerning using the different API's in the public forum "openrobotino", see [xx].

3.4.1 Robotino® View

Robotino® View is a graphical programming language with numerous prepared function blocks you can easily connect via input and output parameters to establish more complicated function diagrams. You can use these function diagrams as subprograms for more complex programming sequences. To build up general programming sequences Robotino® View follows the international standard IEC 61131-3.

You may run Robotino® View on an external PC and Robotino® View communicates directly with the Robotino® Server on the PC 104 via W-LAN in order to control the robot system. The function blocks receive a direct feedback of the hardware components such that you can live interact with the robot system. On the other hand you can download Robotino® View programs into the PC 104 in order to run the applications completely autonomously.

There is a well defined interface to develop own function blocks in C++.

The software can manage different hardware devices and also provides a well defined interface to integrate own hardware devices. Up to now following devices are already integrated:

- The robot system Robotino with the function classes for the
  - drive system,
  - the collision detection via the distance sensors and the bumper,
  - image system including the camera
  - the I/O connector with analogous and digital in- and outputs
  - navigation including odometry and the navigation sensor NorthStar™, see [xx],
  - I/O extension including a gripper, an additional encoder input and power output,
  - power management.
- Joystick with USB interface
- OPC client
- Local PC camera
- .....

The great advantage is now that the software can also manage different hardware devices, in particular various robot systems. This allows to control the common behaviour of different robot systems in terms of one application.

4. Demonstration Competition

In order to justify our proposed concept we will organize a demonstration competition called "Festo Hockey Challenge Cup" during the Robocup 2009 in Graz. There will be selected 6 teams from universities worldwide. The selected team will be provided three Robotinos including the standard hockey equipment. As you see in Fig.1 the hockey plates have no sharp edges such that in case of collisions the bumpers will be not damaged and the possibility that the robots get stuck together will be minimized.

In order to make sure that all teams have equal start conditions the robots will be remote controlled via WLAN. During a competition game it is not allowed to interact with the robot system except the referee requires it. Each team will be assigned an own external access point. The PC's are connected via Ethernet cable to the access point.

4.1 Competition Schedule

First Round: All teams play against each other => 15 matches

Evaluation:

- The winner of each match obtains 3 points,
- the loser team obtains 0 points,
- both teams obtain 1 point if the score of the match is even.
- The ranking is given by the number of points.
- In case of two or more teams have equal number of points the number of goals will determine the ranking. If still there is no clear ranking then there will be a "penalty shootout" between the teams, see 2.3.

Semi Finals:

The first four teams attain the Semi Finals. The first team plays against the fourth team and the second one plays against the third one. The winner teams will be determined by the rule "Best of Three", i.e. the team which wins at first two games between the opponent teams is the winner and will reach the Final. Each match must have a winning team. Otherwise there will be a penalty shootout.

Finals:

The Final will be played by the winner of the Semi Finals. The match for the third place will be done between the loser teams of the Semi Finals.

4.2 Time Schedule

June 29 – July 1:	Setup of the teams and preparation time
July 1 at 14:00:	Setting up the matches for the first round by lottery.
July 2 – July 3:	Matches of the first round
July 4:	Semi Finals
July 5:	Finals
July 5 at 16:00:	Award and Closing Ceremony

4.3 Maintenance

Each team is responsible for its own tool box. Festo will provide spare parts for the standard equipment.

5 References

1. Arras,K.; Siegwart,R.: Acht häufig gestellte Fragen an die Mobilrobotik; SGA Bulletin Nr. 29, (2006)

2. Festo Didactic GmbH & Co.KG: Technical Documentation of Robotino, Denkendorf (2007), http://www.festo-didactic.de

3. Evolution Robotics,Inc.: NorthStar™ Detector Kit ; Pasadena CA 91103, (2005)

4. Kracht,S.;Nielsen,C.: Robots in Everyday Human Environments; Thesis, Aalborg University, (2007)

5. Forum Openrobotino, http://www.openrobotino.org