NimbRo KidSize 2008 Team Description

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Abstract. This document describes the RoboCup Humanoid League team NimbRo KidSize of Albert-Ludwigs-University Freiburg, Germany, as required by the qualification procedure for the competition to be held in Suzhou, China, in July 2008.
Our team uses self-constructed robots for playing soccer. The paper describes the mechanical and electrical design of the robots. It also covers the software used for perception and behavior control.

1 Introduction

The project NimbRo – Learning Humanoid Robots – is running at Albert-Ludwigs-University of Freiburg, Germany, since 2004. Our KidSize team participated with great success at last year's RoboCup Humanoid League competitions in Atlanta, USA. They won the soccer tournament and came in third in the technical challenges. Figure 1 shows the final of the 2 vs. 2 soccer, where our robots met Team Osaka. While the Japanese team used a dedicated goalie and

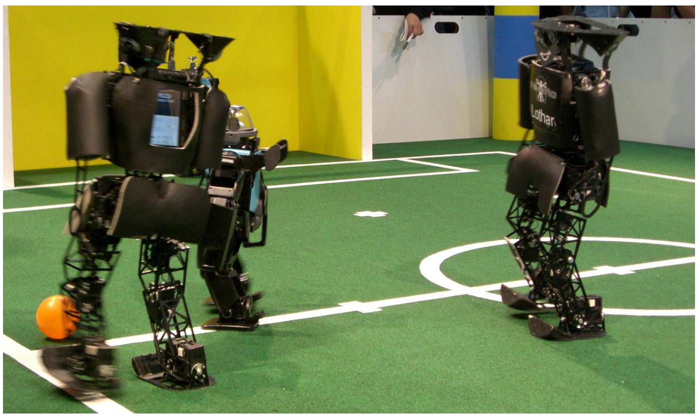

Fig. 1. RoboCup 2007 soccer final: NimbRo vs. Team Osaka. NimbRo won 8:6.

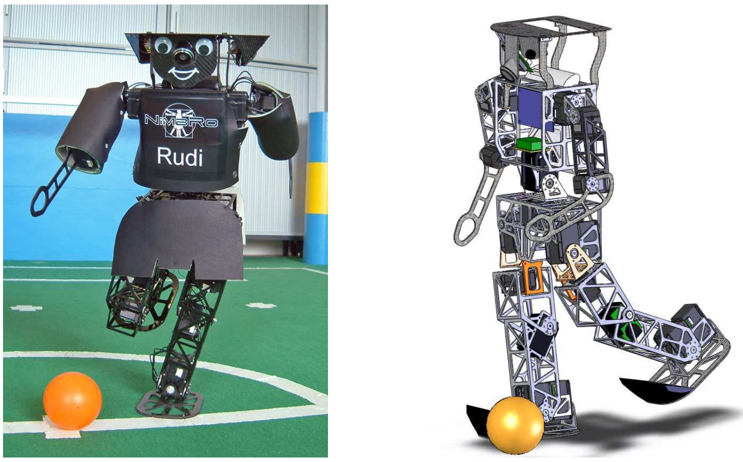

Fig. 2. NimbRo KidSize 2007 robot Rudi and drawing with modified camera head.

one field player, we played with two coordinated field players. Our robots excelled in in one-on-one fights for the ball and in team play. The exiting game was open until the end. Our robots won the final 8:6.

For the 2008 competition, we develop a new vision system for the NimbRo KidSize 2007 robots, which has a limited field-of-view of 180°. The enlarged field and the increased number of players will allow for more team play. This document describes the current state of the project as well as the intended development for the 2008 RoboCup competitions. It is organized as follows. In the next section, we describe the mechanical and electrical design of the robots. The perception of the internal robot state and the situation on the field is covered in Sec. 3. Behavior control in a hierarchy of agents and time-scales is explained in Sec. 4.

2 Mechanical and Electrical Design

Fig. 2 shows Rudi, one of our KidSize 2007 robots. As can be seen, the robot has human-like proportions. Its mechanical design focused on simplicity, robustness, and weight reduction. The KidSize robots have a height of 60cm and weigh 4kg, including batteries.

As compared to the NimbRo 2006 robots [2], which were controlled by a Pocket PC, the 2007 robots have a much stronger main computer and a high-bandwidth vision system. They are controlled by a tiny PC, a Sony Vaio UX, which features an Intel 1.33GHz ULV Core Solo Processor, 1GB RAM, 32GB SSD, a 4.5" WSVGA touch-sensitive display, 802.11a/b/g WLAN, and a USB2.0 interface. Three IDS uEye UI-1226LE industrial USB2.0 cameras provided omnidirectional sight. We are reducing the field-of-view of the robots to 180° in 2008, as can be seen in the right part of Fig. 2. The cameras feature a 1/3" WVGA CMOS sensor, global shutter, and are equipped with ultra-wide angle lenses.

The NimbRo 2007 robots have also stronger actuators, compared to the NimbRo 2006 robots. They are driven by 20 Dynamixel actuators: 6 per leg, 3 in each arm, and two in the trunk. For all leg joints, except hip yaw, and for the trunk pitch joint, we use large RX-64 actuators (116g, 64kg·cm). All other joints are driven by smaller DX-117 actuators (66g, 37kg·cm).

The skeleton of the robots is constructed from aluminum extrusions with rectangular tube cross section. The feet, the forearms, and the robot heads are made from sheets of carbon composite material. The upper part of the robots is protected by a layer of foam and an outer shell of synthetic leather.

Our soccer robots are fully autonomous. They are powered by high-current Lithium-polymer rechargeable batteries, which are located in their hip. Five Kokam 1250mAh cells last for about 25 minutes of operation.

The Dynamixel actuators have a RS-485 differential half-duplex interface. Each robot is equipped with a CardS12X microcontroller board, which manages the detailed communication with all Dynamixels. The Dynamixel actuators have a flexible interface. Not only target positions are sent to the actuators, but also parameters of the control loop, such as the compliance. In the opposite direction, the current positions, speeds, loads, temperatures, and voltages are read back.

In addition to these joint sensors, the robots are equipped with an attitude sensor, located in the trunk. It consists of a dual-axis accelerometer (ADXL203, $\pm$1.5g) and two gyroscopes (ADXRS, $\pm$300 °/s). The four analog sensor signals are digitized with A/D converters of the HCS12X and are preprocessed by the microcontroller.

3 Perception

Our robots need information about themselves and the situation on the soccer field to act successfully.

• **Proprioception:** The readings of accelerometers and gyros are fused to estimate the robot's tilt in roll and pitch direction. The gyro bias is automatically calibrated. Joint angles, speeds, and loads are also available. Temperatures and voltages are monitored to notify the user in case of overheating or low batteries.

• **Visual Object Detection:** The only source of information about the environment for our robots is their three cameras. Our computer vision software captures and interprets images with 752×480 pixels at an aggregated frame rate of about 32fps. The wide field-of-view of the central camera allows the robots to see their own feet and objects above the horizon at the same time (Fig. 3(a)). Two side-cameras have a narrower field-of-view of about 95°. They are heading $\pm$40° away from the robot's central line. Our computer vision software detects the ball, the goals, the corner poles, and other players based on their color in YUV space. We estimate object coordinates in an egocentric frame, based on the inverted projective function of the camera. We correct first for the lens distortion and invert next the affine projection from the ground plane to the camera plane. The objects detected by the three cameras are fused with previous observations in an egocentric representation, shown in Fig 3(b).

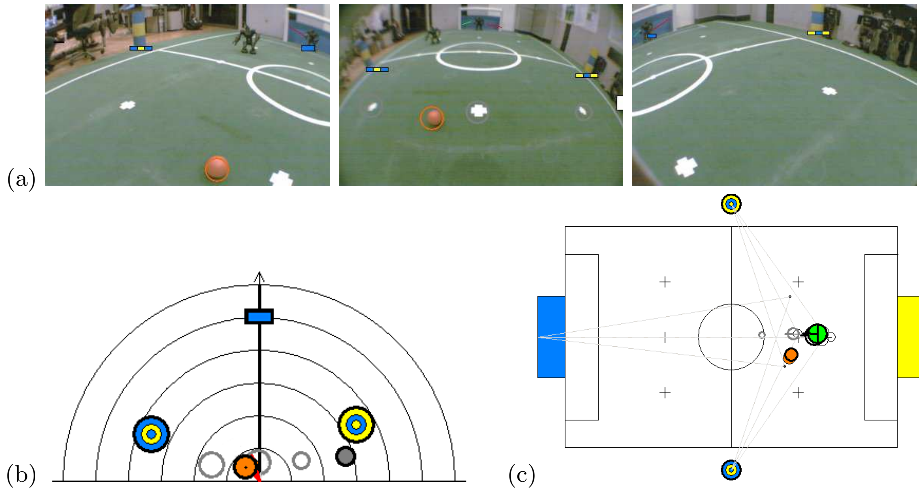

Fig. 3. Visual Perception: (a) three camera images have a combined field-of-view of 180°, with detected objects; (b) egocentric object representation; (c) allocentric representation.

• **Self-Localization:** The relative coordinates suffice for many relative behaviors like positioning behind the ball while facing the goal. To keep track of non-visible goals or to communicate about moving objects with other team members, we need the robot coordinates in an allocentric frame ((x, y)-position on the field and orientation θ). We solve self-localization by triangulation over pairs of landmark observations, i.e. detected goals, goal posts, field markings, and the poles on the side lines, as illustrated in Fig. 3(c). When observing more than two landmarks, the triangulation results are fused based on their confidence. The results of self-localization are integrated over time and a motion model is applied.

As the field-of-view will be restricted to 180° in 2008, we also rely on the field lines for localization [4]. Oriented filters are applied to the green and the white images at two scales. Their responses are grouped to line segments. The center circle is detected and removed. The main orientation of the remaining line segments (modulo 90°) is estimated. For each of the two main orientations, up to two lines are detected in Hough space. The detected lines are matched to a model of the field lines for probabilistic localization.

4 Behavior Control

We control the robots using a framework that supports a hierarchy of reactive behaviors [1]. This framework allows for structured behavior engineering. Multiple layers that run on different time scales contain behaviors of different complexity. When moving up the hierarchy, the speed of sensors, behaviors, and actuators decreases. At the same time, they become more abstract.

The framework forces the behavior engineers to define abstract sensors that are aggregated from faster, more basic sensors. Abstract actuators give higherlevel behaviors the possibility to configure lower layers in order to eventually influence the state of the world.

The control hierarchy of our robots is arranged in an agent hierarchy, where
- multiple joints (e.g. left knee) constitute a body part (e.g. left leg),
- multiple body parts constitute a player (e.g. field player), and
- multiple players constitute a team.

In this hierarchy, we implemented:
- basic skills (e.g. omnidirectional walking, kicking, getting-up behaviors, and goal-keeper motions)
- soccer behaviors (e.g. searching the ball, walking towards the ball, positioning behind the ball, kicking the ball towards the target, dribbling the ball towards the target, avoiding obstacles, controlling the gaze orientation, and goalkeeping)
- tactics and team behaviors (e.g. role assignment, player positioning, ball handling, dribbling around obstacles, dribbling into free space)

Figure 4 shows the the inhibitory structure between these behaviors. More details on the hierarchical reactive control can be found in [3].

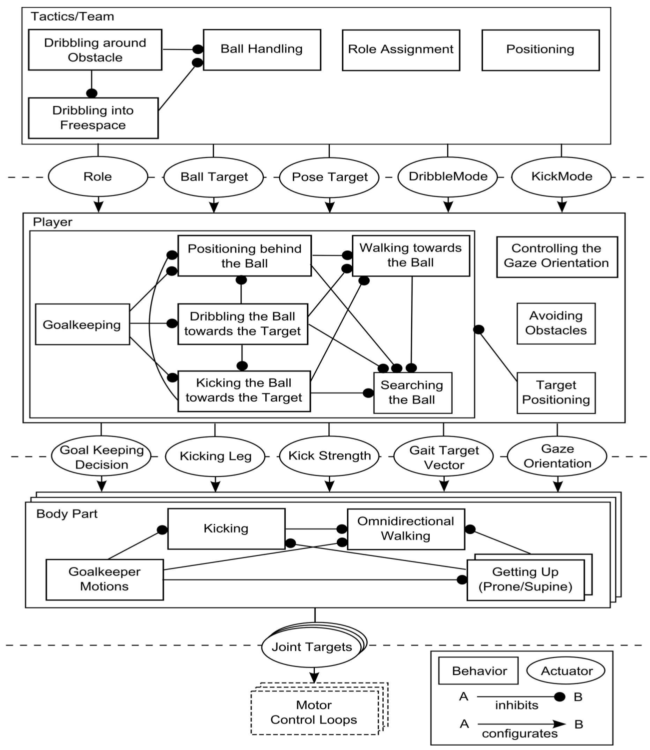

Fig. 4. Actuators, behaviors, and mutual inhibitions within the behavioral hierarchy.

5 Conclusion

At the time of writing, Jan 30th, 2008, we made good progress in preparation for the competition in Suzhou, China. In addition to the modified KidSize 2007 robots, we intend to build a new generation of KidSize robots. We will play test games to select the best robots for RoboCup 2008.

The most recent information about our team (including videos) can be found on our web pages www.NimbRo.net.

Acknowledgements

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Team Members

Currently, the NimbRo soccer team has the following members:

- Team leader: Dr. Sven Behnke
- Staff: Michael Schreiber, Jörg Stückler
- Students: Martin Böhnert, Henrik Kretzschmar, Konrad Meier, and Hannes Schulz

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