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NimbRo 2005 Team Description

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Abstract. This document describes the RoboCup Humanoid League team NimbRo of University of Freiburg in preparation for the competition to be held in Osaka in July 2005.
Our team uses a variety of robots for playing soccer: RoboSapien, Kondo, Toni, and Fritz. These robots are either constructed in our lab, based on a construction kit, or based on a low-cost commercial robot.
The paper describes the robot hardware and software for simulation, perception, behavior control, and communication.

1 Introduction

The project NimbRo – Learning Humanoid Robots has been established at Freiburg University in 2004. At last year's RoboCup competition in Lisbon, we participated with our humanoid robot Alpha in the Freestyle competition (winning a third price with a dance performance) and with an augmented RoboSapien (NimbRo RS) in the Humanoid Walk and the Balancing Challenge (coming in third overall in the Technical Challenge).

This year we aim at full participation at Humanoid League competitions, including soccer games for small robots (HKid), penalty kick for HKid and larger robots (HYouth), and technical challenges.

In order to prepare for the competitions, we constructed a variety of robots, partially from scratch and partially based on commercial construction kits or commercial humanoid robots. These robots have different sizes and are used to investigate different aspects of soccer, ranging from dynamic walking to localization to team play.

This document describes the current state of the project as well as the intended development for the 2005 RoboCup competitions.

2 Robots

2.1 Servo-based Robots Constructed in Our Lab

Figure 1(a) shows our robot Toni, ready to kick the ball. It is 74cm tall and has a total weight of 2.2kg. Toni is driven by 18 servos: 6 in each leg and 3 in each arm. Its mechanical design focused on human-like proportions and light weight.

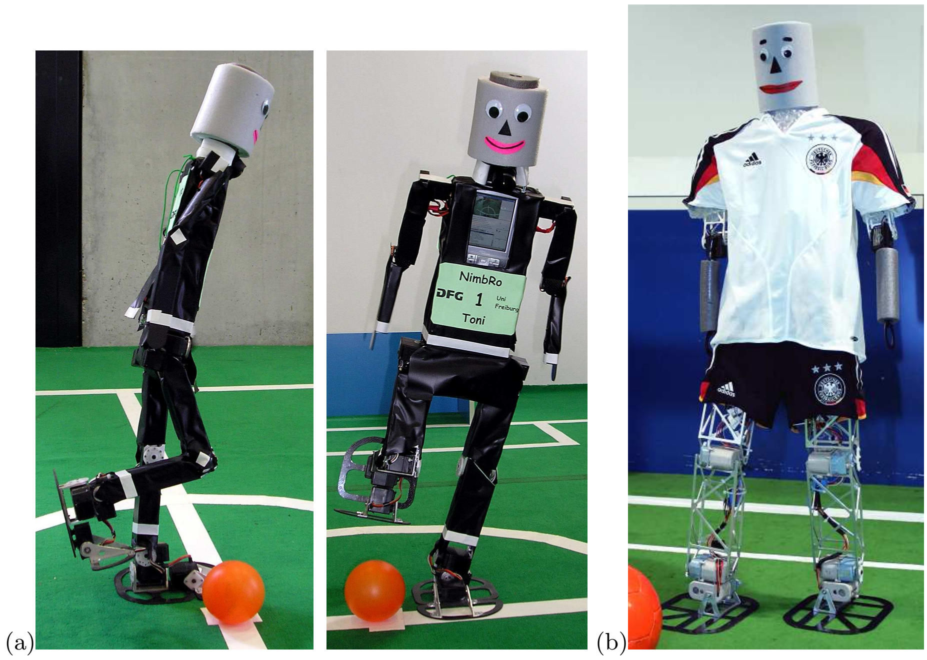


Fig. 1. (a) Two views of Toni; (b) Fritz.

In order to be able to over-extend the leg, we added a toes joint in its foot plate. This allows it to dynamically walk in a human-like manner with a straight stance leg and toes bending before toes-off.

Toni is fully autonomous. It is powered by Lithium-polymer batteries. Three HCS12 microcontrollers generate target signals for the servos and read back the servo positions and duties. They also interface an attitude sensor consisting of two accelerometers and two gyros. The microcontrollers communicate with each other via a CAN bus and with a main computer via a RS232 serial line.

The main computer runs behavior control, computer vision, and wireless communication [3]. In the photo Toni is equipped with a Pocket PC that has a wide-angle camera in its CF slot. We also tested a small PC as main computer which interfaces two wide-angle cameras via USB. This PC will control Fritz, shown in Fig. 1(b).

Fritz is 120cm tall and has a weight of about 6kg. Currently, it has 16DOF: 5 in each leg and 3 in each arm. The joints are driven by servos, controlled by three HCS12 boards. Fritz also has LiPoly batteries.

2.2 Servo-based Construction Kit

Our robot shown in Figure 2(a) is based on the KHR-1 construction kit made by Kondo [5]. In its original configuration, the Kondo robot is driven by 17 servos: 5 in each leg, 3 in each arm, and one used as head. It is 34cm tall and has a total

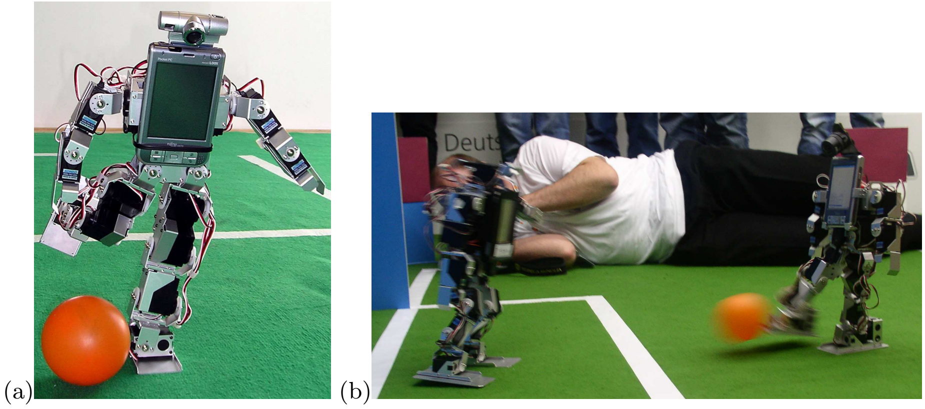


Fig. 2. (a) Augmented Kondo robot. (b) Penalty Kick demonstrations at German Open 2005: Darmstadt Dribblers vs. NimbRo.

weight of 1.2kg. We do not use the head servo, added two rotational servos in its feet, and augmented the robot with a Pocket PC equipped with a wide-angle camera. The Pocket PC interfaces the servo control boards via a RS232 serial line. It runs behavior control, computer vision, and wireless communication. The Kondo robot is powered by NiCd batteries.

2.3 Low-cost Commercial Robot Base

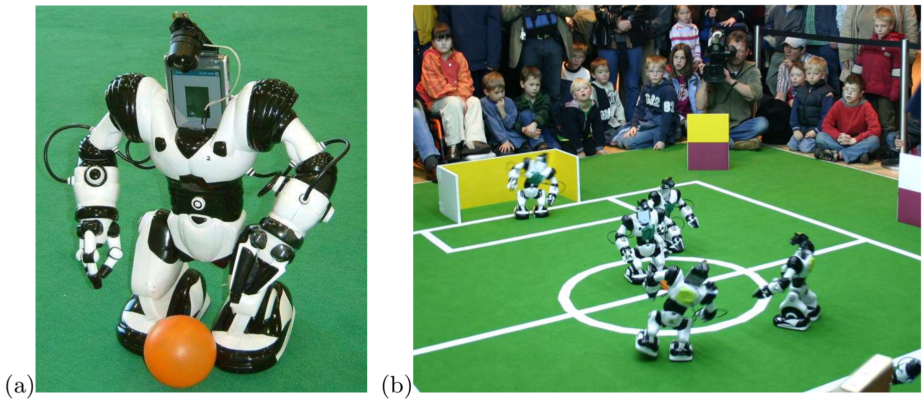


Fig. 3. (a) Augmented RoboSapien; (b) RoboSapien demonstration games at German Open 2005: Brainstormers Osnabrück vs. NimbRo.

Figure 3(a) shows one of the augmented RoboSapiens we use to investigate localization and team play. The RoboSapien base has been developed by M.

Tilden and is marketed by WowWee for the toy market [7]. It is driven by 7 DC motors and powered by batteries located in its feet. The low center of mass makes RoboSapien very stable. Using three motors, it can walk dynamically with two speeds in sagittal direction. It can also turn on the spot. The other four motors move its arms.

The original RoboSapien is controlled by the user with a remote control. We made it autonomous using a camera-equipped Pocket PC [2]. The Pocket PC sends motion commands to the robot base via infrared. It runs higher-level behavior control, computer vision, and wireless communication.

Due to the low price of this humanoid robot (currently about 700 Euros + tax, including Pocket PC, camera, and wide-angle lens), we were able to augment five of these robots. In a lab project, we prepared for demonstration games against the Brainstormers Osnabrück, which took place take place at RoboCup German Open in Paderborn (April 2005). Fig. 3(b) shows both teams.

3 Simulation

In order to be able to design behaviors without access to the real hardware, we implemented a physics-based simulation for the robots Toni, Kondo, and Fritz. This simulation is based on the Open Dynamics Engine [6]. We also simulated two teams of augmented RoboSapiens.

4 Perception

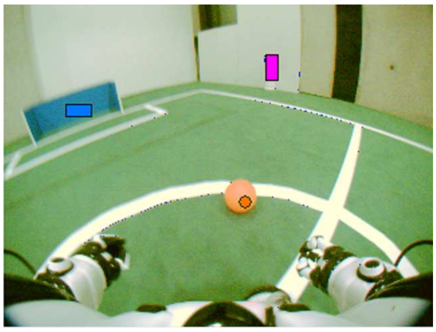
Our robots need information about themselves and about the world around them to act successfully.

We fuse the accelerometer and gyro readings of Toni to obtain an estimate of its tilt and keep track of its leg joint angles and motor duties by interpreting its potentiometer voltage.

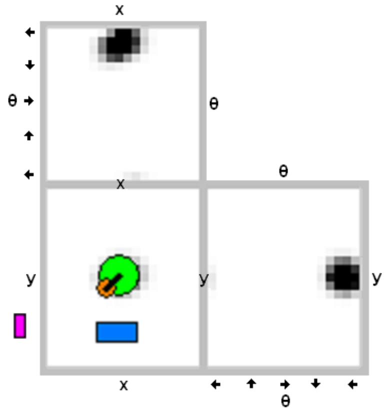
The only source of information about the environment of our robots is their camera. The wide-angle CF-camera allows seeing the ball at the robots feet, the goal, and poles simultaneously (see Fig. 4(a)).

Our computer vision software detects these key objects based on their color and estimates their coordinates in an egocentric frame (distance to the robot and angle to its orientation). This suffices for many relative behaviors, like positioning behind the ball facing the goal.

To implement global team behaviors, such as kick-off, we need the robot coordinates in an allocentric frame (position on the field, orientation). We estimate these using a probabilistic Markov localization method that integrates egocentric observations and motion commands over time. As proposed by Fox, Burgard, and Thrun [4] this method uses a three-dimensional grid (x, y, θ), shown in Figure 4(b). Based on robot localization, we fuse local ball observations of multiple robots to a global ball estimate.



(a)



(b)

Fig. 4. (a) Image captured from RoboSapien's perspective while it was turning. Detected objects: goal (blue horizontal rectangle), ball (orange circle), and pole (magenta vertical rectangle); (b) Three two-dimenensional projections of the grid representing the probability distribution of robot poses (x, y, θ). The green circle is drawn at the estimated robot location (x, y). The black line represents its estimated orientation θ. The detected objects are drawn relative to the robot.

5 Behavior Control

We control our robots using a framework that supports a hierarchy of reactive behaviors [1]. For the servo-based robots, we generate target-positions for the individual joints at a high rate.

To abstract from these many degrees of freedom, the next higher level generates targets for body parts, such as leg extension and leg angle. On this layer, we implemented dynamic walking.

Toni's maximum walking speed is about 20cm/s. Toni is not only able to walk forward and backward, but it can also walk to the side and turn on the spot. By blending these gait directions, we generate omnidirectional walking. We used this interface to implement higher-level behaviors, like approaching the ball and dribbling. In addition to walking, we implemented a kicking behavior for Toni. Toni demonstrated its soccer skills at RoboCup German Open 2005, where it performed penalty kicks against Mr. DD of Darmstadt Dribblers. Toni approached the ball, slowed down, and kicked it strongly towards the goal (see Fig. 5).

The Kondo robot is able to walk at a speed of up to 14cm/s. We implemented omnidirectional walking, kicking, goalie behaviors, and getting-up behaviors for Kondo. Kondo also performed penalty kicks at German Open 2005 (see Fig. 2(b)). Currently, we are working on automatically optimizing Kondo's gait pattern.

Since we cannot change the gait of RoboSapien, behavior control for it focused on higher-level issues, like positioning on the field and team play.

Fig. 5. Penalty Kick demonstrations at German Open 2005: Mr. DD vs. Toni.

6 Communication

All our robots are equipped with wireless network adapters. We use the wireless communication to transmit debug information to an external computer, where it is logged and visualized. This computer is also used to fuse local views to a team view and to compute team behaviors, such as the assignment of roles to the individual players. The wireless network is also used for transmitting the game state (kickoff, penalty ...) to the robots.

7 Conclusion

At the time of writing, May 10, 2005, we have several walking robots and made good progress in perception and behavior control. Currently, we are building two more servo-based robots for the HKid league. We will use test games to select the best robots for RoboCup 2005.

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: Dr. Maren Bennewitz and Jürgen Müller
- Students: Tobias Langner, Julio Pastrana, Michael Schreiber, Johannes Schwenk, Hauke Strasdat, Jörg Stückler, and Konstantin Welke

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