NimbRo TeenSize 2011 Team Description

Sven Behnke and Marcell Missura

Rheinische Friedrich-Wilhelms-Universität Bonn
Computer Science Institute VI: Autonomous Intelligent Systems
Römerstr. 164, 53117 Bonn, Germany
{ behnke | missura } @ ais.uni-bonn.de
http://www.NimbRo.net

Abstract. This document describes the RoboCup Humanoid League team NimbRo TeenSize of Rheinische Friedrich-Wilhelms-Universität Bonn, Germany, as required by the qualification procedure for the competition to be held in Istanbul in July 2011.

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

Our TeenSize team participated with great success at last year's RoboCup Humanoid League competition in Singapore. The robots won the first 2 vs. 2 soccer tournament, the technical challenges, and received the Louis Vuitton Best Humanoid Award. Figure 1 shows the final soccer game, where our robots met CIT Brains from Japan. The field players of both teams were able to find the ball and to kick it reliably and both teams had goalies able to quickly jump to the ground. Because our robot Dynaped was usually the first at the ball, the game ended 10:0 for NimbRo.

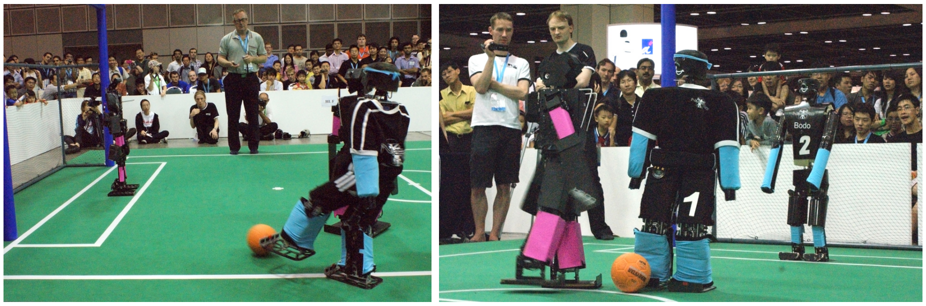


Fig. 1. RoboCup 2010 TeenSize finale: NimbRo vs. CIT Brains. Our team played with the robots Dynaped (field player) and Bodo (goalie).

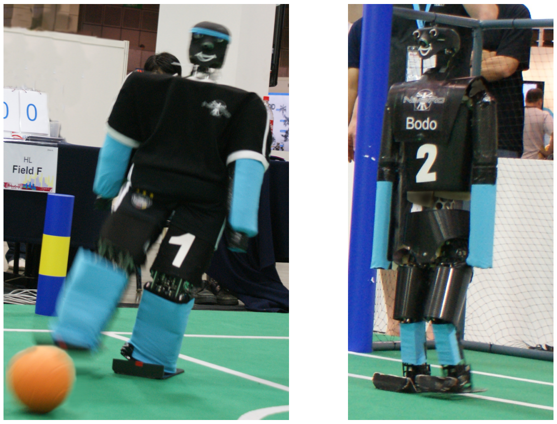


Fig. 2. NimbRo TeenSize robots Dynaped and Bodo.

In 2011, the TeenSize class will enlarge the field. This will make the soccer games even more challenging. We will continue to use the NimbRo TeenSize robots Dynaped and Bodo. We are also constructing new TeenSize robots, which not only survive a fall, but are also able to get-up afterwards. We continuously improve the computer vision and behavior control software.

This document describes the current state of the project as well as the intended development for the RoboCup 2011 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. The generation of soccer behaviors in a hierarchy of agents and time-scales is explained in Sec. 4.

2 Mechanical and Electrical Design

Fig. 2 shows our two TeenSize robots: Dynaped and Bodo. As can be seen, the robots have human-like proportions. Their mechanical design focused on simplicity, robustness, and weight reduction.

Dynaped is 105 cm tall, and weighs 7 kg. The robot has 13 DOF: 5 DOF per leg, 1 DOF per arm, and one joint in the neck that pans the head. Its legs use a parallel kinematics, which keeps the hip parallel to the ground in sagittal direction. The joints are driven by master-slave pairs of Robotis Dynamixel EX-106 actuators.

Bodo is 103 cm tall and has a weight of about 5 kg. The robot is driven by 14 Dynamixel actuators: 6 per leg and 1 in each arm. For all leg joints, except hip yaw, we use large RX-64 actuators. All other joints are driven by smaller DX-117 actuators.

The skeleton of the robots is constructed from aluminum extrusions with rectangular tube cross section. In order to reduce weight, we removed all material not necessary for stability. The feet and other flat parts are made from sheets of

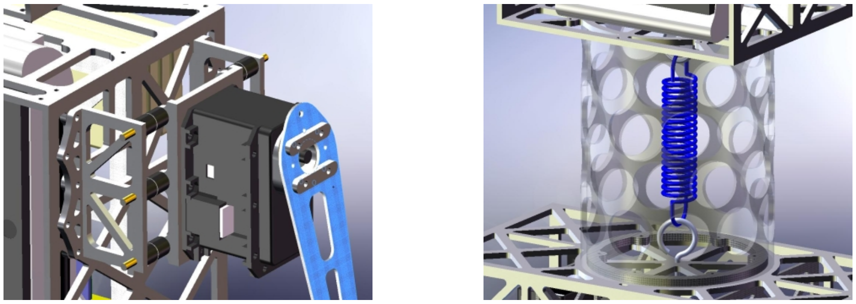


Fig. 3. Dynaped's mechanical precautions against damage resulting from falls. The shoulder (left) is fixed to the frame by six flexible struts made from hard rubber. The hip (right) is a pull linkage with a spring that holds the torso in place.

carbon composite material. For protection, we included a layer of foal between the outer shell of the robots and their skeleton. As shown in Fig. 3, Dynaped and Bodo have a mechanical fuse between the hip and the spine, which allows the robots to jump quickly to the ground as a goalie.

The robots are controlled by an UMPC, a Sony Vaio UX, which features an Intel 1.33 GHz ULV Core Solo Processor, 1GB RAM, 32 GB SSD, a touch-sensitive display, 802.11a/b/g WLAN, and a USB 2.0 interface.

The robots are also equipped with a HCS12X microcontroller board, which manages the detailed communication with all joints via an 1 Mbaud RS-485 bus. The microcontroller also read in a dual-axis accelerometer and two gyroscopes. This board communicates with the main computer via a RS-232 serial line at 115 KBaud. The robots are powered by high-current Lithium-polymer rechargeable batteries, which are located in their lower back and last for about 20 min of operation.

3 Perception

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

3.1 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 and the low-frequency components of the tilt estimated from the accelerometers are combined with the integrated turning rates to yield an estimate of the robot's attitude that is insensitive to short linear accelerations. Joint angles, speeds, and loads are also available. Temperatures and voltages are monitored to notify the user in case of overheating or low batteries.

3.2 Computer Vision

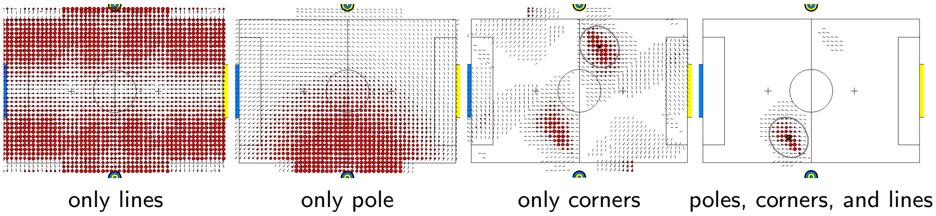
We capture and process YUV images. Pixels are color-classified using a color look-up table. In the downsampled color-classified image we detect the ball, the goals, the poles, goal-posts, restart markers, field line features, obstacles, team mates, and opponents by color and size. We estimate distance and angle to each feature by removing radial lens distortion and by inverting the projective mapping from field to image plane. For field line features at corners and T-junctions, we also estimate their orientation relative to the robot.

With limited FOV, parts of the soccer field and the dynamic world state can not be perceived directly. This knowledge has to be inferred and estimated indirectly instead. The goalkeeper, for example, must estimate its pose within the goal through localization using a limited set of visible landmarks. Also, it is valuable to distribute knowledge of the ball position among the players in a team using localization information.

The robot can not perceive its motion directly. Instead, we model its motion based on its gait target velocity. The model accounts for the high noise in its execution. Also, the distance and angle measurements to landmarks are subject to high noise, especially due to inclinations of the robot during walking.

As the goals, the poles, and the goal posts are not sufficient for our localization purposes, we use landmarks like the restart markers, field line corners, and field line T-junctions in addition. We estimate the robot's pose on the field using a particle filter (MCL) [7].

To handle unknown data association of unidentified landmarks, we sample the data association on a per-particle basis. The association of field line corner and T-junction observations to landmarks also utilizes landmark orientation. The belief resulting from different features is illustrated in Fig. 4. Further details can be found in [5].



only lines only pole only corners poles, corners, and lines

Fig. 4. Particle filter localization belief based on observed landmarks.

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.

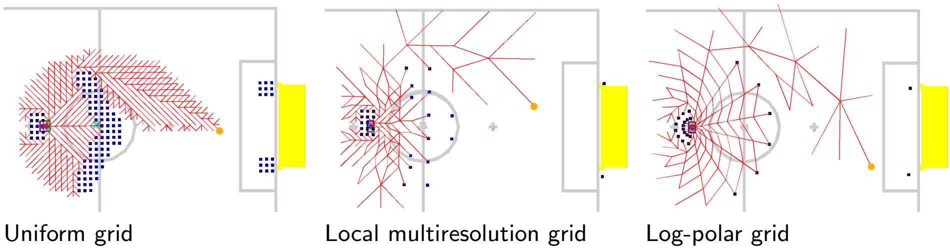


Fig. 5. Node expansions performed by the A* path planning on different space discretizations. Obstacles are shown with blue dots and the target is shown as orange dot.

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 higher-level 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)
- soccer behaviors (e.g. searching the ball, positioning behind the ball), and
- tactics and team behaviors (e.g. role assignment, player positioning).

Currently, we are working on a capture-step controller, which adjust the timing and location of the next step, based on the feedback of the attitude sensor. This controller uses the linear-inverted pendulum model [2]. Initial experiments with Dynaped in the lateral plane showed that the controller can reject large disturbances while the robot is walking. After one capture step, the robot regains its balance and continues its stable walking pattern.

Of special importance in the TeenSize Dibble-and-Kick is the goalie motion. We designed motion sequences that minimize the time to dive from an upright standing posture to the ground [3].

For implementing a footstep planning gait control, we developed a step prediction model that estimates the location of the next footstep, given the walking speed. We used motion capture data to estimate the parameters of the prediction model and to verify the accuracy of the predicted footstep locations [4].

For path planning, we implemented two different local multiresolution methods, based on robot-centric Cartesian and log-polar space discretizations. The node expansions of A* search in a typical game situation are shown in Fig. 5 in comparison to a uniform grid. We evaluated our approach in simulation and with real robots. Our experiments showed that the multiresolutional methods are able to plan in few milliseconds, without scarifying the quality of planned paths [6].

5 Conclusion

At the time of writing, Jan 28th, 2011, we made good progress in preparation for the competition in Istanbul. We will continue to improve the system for RoboCup 2011. The most recent information about our team (including videos) can be found on our web pages www.NimbRo.net.

Acknowledgements

This project has been supported by Deutsche Forschungsgemeinschaft (German Research Foundation, DFG) under grant BE 2556/2.

Team Members

Currently, the NimbRo soccer team has the following members:

- Team leader: Prof. Sven Behnke
- Members: Marcell Missura, Matthias Nieuwenhuisen, and Michael Schreiber

References

1. Sven Behnke and Jörg Stückler. Hierarchical reactive control for humanoid soccer robots. *International Journal of Humanoid Robots (IJHR)*, 5(3):375–396, 2008.
2. S. Kajita, F. Kanehiro, K. Kaneko, K. Yokoi, and H. Hirukawa. The 3D linear inverted pendulum mode: A simple modeling for a bipedwalking pattern generation. In *Proceedings of IROS*, pages 239–246, 2001.
3. Marcell Missura, Tobias Wilken, and Sven Behnke. Designing effective humanoid soccer goalies. In *Proc. of International RoboCup Symposium, Singapore*, 2010.
4. Andreas Schmitz, Marcell Missura, and Sven Behnke. Learning footstep prediction from motion capture. In *Proceedings of International RoboCup Symposium, Singapore*, 2010.
5. Hannes Schulz, Weichao Liu, Jörg Stückler, and Sven Behnke. Utilizing the structure of field lines for efficient soccer robot localization. In *Proceedings of International RoboCup Symposium, Singapore*, 2010.
6. Ricarda Steffens, Matthias Nieuwenhuisen, and Sven Behnke. Multiresolution path planning in dynamic environments for the standard platform league. In *Proceedings of 5th Workshop on Humanoid Soccer Robots at Humanoids 2010, Nashville*, 2010.
7. S. Thrun, W. Burgard, and D. Fox. *Probabilistic Robotics.* MIT Press, 2005.