

# Team Description for RoboCup 2010

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### 1 Introduction

*B*-Human is a joint RoboCup team of the Universität Bremen and the German Research Center for Artificial Intelligence (DFKI). The team consists of numerous undergraduate students as well as two researchers. The latter have already been active in a number of RoboCup teams such as the GermanTeam and the Bremen Byters (both Four-Legged League), B-Human and the BreDoBrothers (Humanoid Kid-Size League), and B-Smart (Small-Size League).

We entered the Standard Platform League already in 2008 as part of the BreDoBrothers, a joint team of the Universität Bremen and the Technische Universität Dortmund, providing the software framework, state estimation modules, and the getup and kick motions for the Nao. For RoboCup 2009, we discontinued our Humanoid Kid-Size League activities and shifted all resources to the SPL, starting as a single location team after the split-up of the BreDoBrothers. Since its start, the team B-Human has won every match and tournament it participated in. In 2009, we won the RoboCup in Graz (including the technical challenge) as well as the RoboCup German Open in Hannover. This year, we already won the RoboCup German Open in Magdeburg, and we intend to repeat our success of last year by also winning the RoboCup in Singapore.

This team description paper provides a brief overview of our relevant publications since RoboCup 2009 (cf. Sect. 2) and of current work that is about to become used during the next competition (cf. Sect. 3).

B-Human currently consists of the following people who are partially shown in Fig. 1:

- Students. Alexander Fabisch, Arne Humann, Benjamin Markowsky, Carsten Könemann, Christian Thedieck, Daniel Honsel, Emil Huseynli, Felix Wenk, Fynn Feldpausch, Jonas Peter, Martin Ring, Max Trocha, Michael Mester, Ole Jan Lars Riemann, Philipp Kastner, Bastian Reich, Thomas Liebschwager, Tobias Kastner, Wiebke Sauerland.
- Senior Students. Alexander Härtl, Armin Burchardt, Colin Graf, Ingo Sieverdingbeck, Judith Müller, Katharina Gillmann, Thijs Jeffry de Haas.



Fig. 1. The team B-Human at the awards ceremony of the RoboCup German Open 2010

Researcher. Tim Laue. Senior Researcher. Thomas Röfer (team leader).

## 2 Publications since RoboCup 2009

We are convinced that code releases are an important part of sharing scientific works with others. After RoboCup 2009, we therefore released our code – together with a comprehensive documentation [1] – to the public on our website http://www.b-human.de/publications.php. We hope this act motivates other teams to release their code, too, or to use our code as a basis. At the RoboCup German Open 2010, the runner up *NimbRo* used our framework as starting point for their own development.

Probabilistic state estimation has always been one of our main research topics. Therefore, we intensively worked on a precise self-localization that proved to be an important part of our successes in soccer competitions as well as in the technical challenge. In [2], we described different state estimation problems that arise e.g. from an inaccurate proprioception, the sparsity of unique features in the robot's environment, or the perception of false positives. To tackle these problems we presented approaches for reliable and efficient feature extraction together with the features' incorporation into a robust state estimation process.

Particle filter-based approaches have proven to be capable of efficiently solving the self-localization problem in RoboCup scenarios and are therefore applied by many participating teams including us. Nevertheless, they always require a proper parameterization – for sensor models and dynamic models as well as for the configuration of the algorithm – to operate reliably. In [3], we presented an approach for optimizing all relevant parameters

by using the Particle Swarm Optimization algorithm. The approach has been shown to be capable of finding a parameter set that leads to more precise position estimates than our previously used hand-tuned parameterization.

In the Standard Platform League scenario, robot kidnapping is an event that occurs regularly. Therefore, the insertion of new particles into the sample set – the so-called sensor resetting [4] – becomes necessary for efficiently recovering from delocalization. However, this approach often leads to a multimodal probability distribution as samples might become clustered at different positions within the state space. In [5], we presented a robust and computationally efficient algorithm for extracting clusters from a sample set in robot self-localization scenarios.

The estimation of a robot's world model can be improved by actively sensing the environment through considering the current world state estimate through minimizing the entropy of an underlying particle distribution. Being originally computationally expensive, this approach can be optimized to become executable in real-time even on a robot with limited resources such as the Nao. This has been demonstrated in [6] for self-localization as well as for ball tracking.

A second main research topic is the development of stable and efficient robot motions. In [7], we presented a robust closed-loop gait for the Nao. The active balancing used in the approach is based on the pose of the torso of the robot, the estimation of which has been described, too. In addition, we presented an analytical solution to the inverse kinematics of the Nao, solving the problems introduced by the special hip joint of the Nao.

Complex motions like kicking a ball into the goal are becoming more important in RoboCup leagues such as the Standard Platform League. Thus, there is a need for motion sequences that can be parameterized and changed dynamically. In [8], we presented a motion engine that translates motions into joint angles by using trajectories. These motions are defined as a set of Bezier curves that can be changed online to allow adjusting, for example, a kicking motion precisely to the actual position of the ball. During the execution, motions are stabilized by the combination of center of mass balancing and a gyro feedback-based closed-loop PID-controller.

## **3** Current Projects

In addition to the previously described, already published work, some new projects are still under development, and they are expected to become finished until RoboCup 2010. This includes significant improvements of our walking approach, vision-based robot detection, and the implementation of new goalkeeper skills.

#### 3.1 Walking

Since the last RoboCup, we advanced our closed-loop gait [7] by creating a more sophisticated model for the center of mass movement that is based on two alternating inverted pendulums (cf. Fig. 2) and a preview controller. This model allows eliminating the need of a double-support phase by dynamically adjusting the point in time at which the support leg alternates. Thus, the load on the joints for bridging over larger distances can be reduced. Furthermore, the stabilization methods used to keep the balance of the gait were partially integrated into the model to react on external disturbances in a farsighted



Fig. 2. Schematic representation of two alternating inverted pendulums

manner. The present results are very promising since the maximal reachable velocity has almost doubled.

The gait was already tested successfully at the RoboCup German Open 2010 and gained a distinct advantage against most other teams. Until the world championship, we plan to increase the stability of the walk at low velocities to avoid losing balance while scuffling around the ball.

#### 3.2 Robot Detection

During all previous tournaments, including the RoboCup German Open 2010, we have only been able to detect opponent robots via the ultrasonic sensors. This approach is quite inaccurate and only applicable for short distances.

Therefore, we are currently working on the visual detection of opponent robots. Our approach is based on color segmentation and the subsequent detection of pink and blue regions representing the team markers. Afterwards, the degree of whiteness of the marker regions' environment is determined by means of a scan line grid that is orthogonal to the principal axis of inertia of the team marker region (cf. Fig. 3a). For filtering the data provided by this perception module, we built a model that is updated by a Kalman filter.

Our first goal is to use this new feature to aim more accurately at the largest part of the opponent goal that is not blocked by the goal keeper or other robots (cf. Fig. 3b).

#### 3.3 Goalkeeper

In RoboCup 2009, teams such as *BURST* or *TT-UT-Austin Villa* demonstrated that a diving goalkeeper can be very effective to block long-distance shots. However, a dive also bears the risk of damaging the robot. Hence, we carefully created a diving motion that allows our goalie to dive without taking any serious damage. In [9] it is described that the horizontal acceleration of the goalkeeper's body is the most important one for a quick dive. In contrast to the humanoid robots described in that paper, the Nao has no constructional features that compensate for the impact of hitting the ground. Therefore, we minimize the distance the Nao falls during the dive by starting the dive from a crouching body posture. In fact, we assume that the dive puts less strain on the robot that the following getup motion.



Fig. 3. a) Blue team marker with its principal axis of inertia and orthogonal scanlines. b) A robot's model of the world before kickoff including the largest free part of the opponent goal (red part of the yellow goal line) and the estimated positions of other robots on the field (blue circles).

At first, the goalie positions itself within its goal. After reaching its position in the middle of the goal facing towards the opponent goal, the keeper crouches (see Fig.4a and Fig.4b) and looks straight at ball. To maintain a proper self-localization, the goalie regularly looks at defined points in its penalty area for correcting its state estimate. Whenever the ball changes its position to the left or right side of the goalie beyond a defined threshold, the goalie adjusts its position to face the ball again.

If the ball is rolling towards the goal, the goalie has to select from a given set of actions: staying crouched, spreading the legs, or diving. The decision is made by considering the velocity and the distance of the ball estimated by a particle filter [1]. The estimates are used to calculate both the remaining time until the ball will intersect the lateral axis of the goalie and the position of intersection. If the ball rolls straight towards the goalkeeper, or it is expected to clearly miss the goal, the keeper remains crouched. In case of a close intersection, the goalie changes to a wide defensive posture to increase its range (for approximately four seconds, conforming to the rules of 2010). The diving is initiated when the ball intersects the goalkeeper's lateral axis in a position farther away from the farthest possible point of the defensive posture. To avoid damage to the Nao, e. g. by jumping into a goal post, the position of the goalie inside the penalty area as well as the remaining time for the ball to reach the goal are considered. Thus, the goalie would not dive if the diving took more time than is left for the ball to reach the goal.

### 4 Conclusions

B-Human has performed considerable research during the past year to push the Standard Platform League forward to close the gap to the Humanoid League. In some areas, the Standard Platform League is already ahead, e.g., there are less artificial features on the field and the goals are more realistic, i. e. they have a net. In terms of speed and reactivity, B-Human would still be in the better half of the Humanoid League, but currently we do not yet reach the top in-game walking speeds of the best Humanoid League teams.



Fig. 4. Penalty shootout practice during the RoboCup German Open 2010: a) The goalie in its crouching position, while the striker starts to kick. b) The striker aims the ball at the right corner. c) tThe goalie starts diving. d) The goalie has successfully caught the ball.

However, doubling the walking speed from one year to the next is still a huge step in the right direction.

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