Nao Devils Dortmund

Team Description for RoboCup 2010

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1 Introduction

The *Nao Devils Dortmund* are a RoboCup team by the Robotics Research Institute of TU Dortmund University participating in the Nao Standart Platform League since 2009 and in 2008 as part of the team *BreDoBrothers*.

2 Relevant Achievements in RoboCup

The *Nao Devils Dortmund* have their roots in the teams *Microsoft Hellhounds* (and therefore part of the *German Team*), *DoH!Bots* and *BreDoBrothers*. The senior team members have already been part of a number of successes, such as winning the RoboCup World Championship twice with the *GermanTeam* (2004 and 2005), winning the RoboCup German Open 2005, the Dutch Open and US Open 2006 with the *Microsoft Hellhounds*, and winning the Four-Legged League Technical Challenge two times (2003 by the GermanTeam, 2006 by the *Microsoft Hellhounds*). In parallel to these activities, the *BreDoBrothers* started a joint team of TU Dortmund University and University Bremen in the Humanoid League which participated in RoboCup 2006. The *DoH Bots!* designed and constructed a humanoid robot from scratch and participated in the Humanoid League of RoboCup 2007. The *BreDoBrothers* participated successfully in the first Nao Standard Platform league in 2008, reaching the quarter finals being undefeated during round robin. Recently the *Nao Devils* placed 3rd out of 9 teams in the German Open 2009 and 3rd out of 24 teams in the RoboCup 2009.

3 Research Goals

The cooperative and competitive nature of robot soccer in the Standard Platform League provides a suitable test bed for a broad research area. The *Nao Devils*' research is mainly focused on Computer Vision, Probabilistic State Estimation, and Machine Learning. Naturally Biped Walking is also thoroughly addressed.

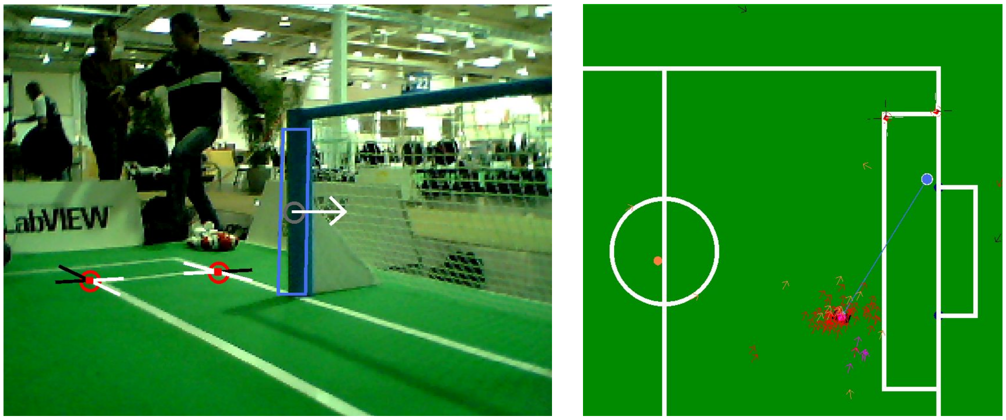
3.1 Computer Vision

In the field of computer vision, algorithms for performing structure preserving non-linear noise reduction on computationally constrained robotic platforms [1] have been presented, as well as a set of techniques to improve color based vision on embedded platforms (color table generalization based on an irradiation model, automatic vignetting correction) [2]. The work on automatic image vignetting correction has been further extended to take into account differences in color response from different cameras in a team of robots, and the optimization technique has been refined with the adoption of Evolutionary Strategies [3].

A recent addition comes in the form of an active vision module replacing the common strategy to simply move the robots head continuously to cover as much as possible of the robot's environment. The method to be presented on the RoboCup symposium 2010 [4] takes into account the localization belief given as a particle distribution of the Monte Carlo localization described in the next section and computes the head motion with expected optimal gain with respect to Entropy minimization of said localization belief.

3.2 Probabilistic State Estimation

One main focus of research is on Bayesian filters, where several enhancements for real time vision-based Monte Carlo localization systems [5] have been presented, and the approach based on the detection of field features without using artificial landmarks has won the "almostSLAM" Technical Challenge at RoboCup 2005 [6].

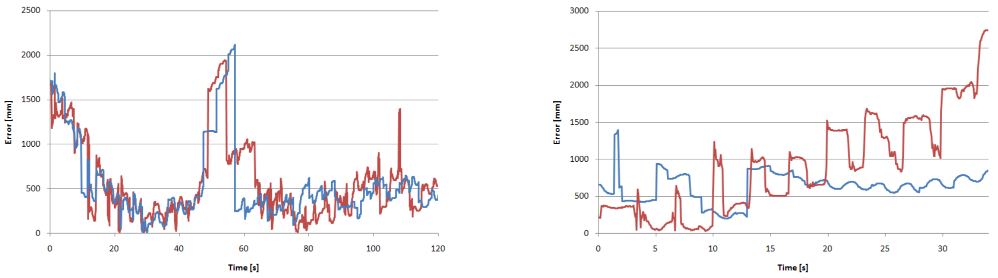


(a) Image processing result. (b) Particle filter localization.

Fig. 1. Performance of the cognition process.

In the field of cooperative object tracking and sensor fusion a distributed approach to particle filtering to model the ball position collectively as a team has been presented in [7]. Opponent player tracking is a generalization of ball tracking, made more complex by the data association problem (all players in a team look identical) and an increased difficulty in visual recognition and distance measurement due to the complex shape of the robots. As a first approach it was dealt with cooperative robot tracking using a bank of particle filters dynamically allocated depending on the estimated number of players in the field [8].

Current work includes robust cooperative world modeling and localization on concepts based on multi robot SLAM. In this joint modeling of the robot's state a particle filter estimates the robot's pose. Clusters of particles are combined into super-particles which map the dynamic environment using a number of Kalman filters. This represents an approximation of FastSLAM and both decreases the integration of odometry error compared to robot-centric local modeling (see figure 2) and allows resolving multi-modal localization belief states using shared information. A detailed presentation of the approach is currently submitted but not published, yet.



(a) No gain for frequently observed robots.

(b) Tracking of infrequently observed robots significantly improved.

Fig. 2. Advantage by unified (blue) compared to separate robot-centric modeling (red).

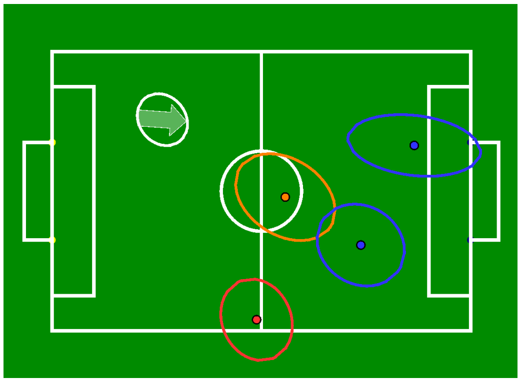
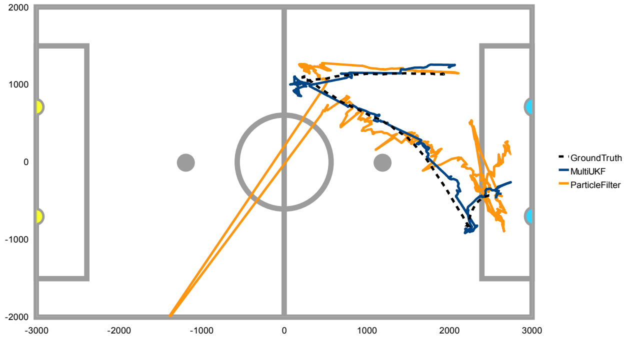
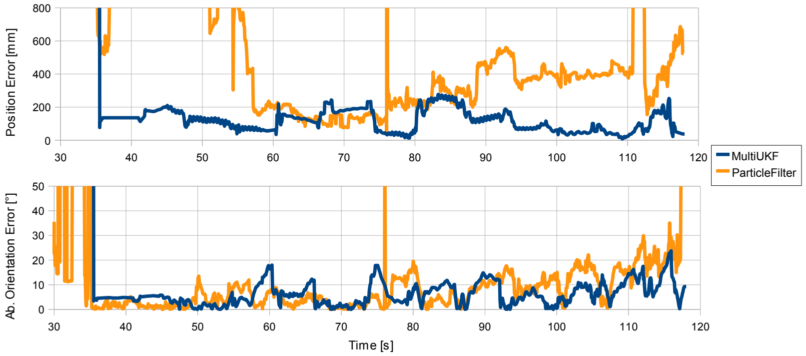


Fig. 3. Modeling of the robot's dynamic environment.

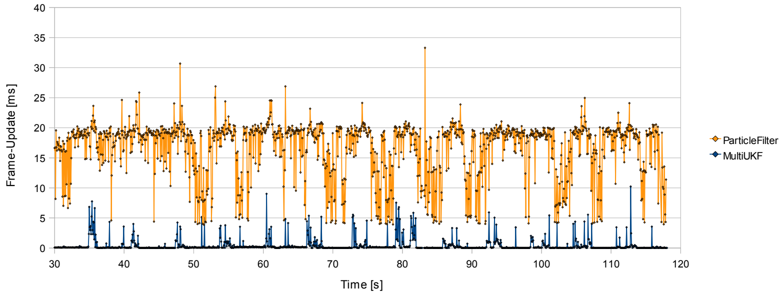
While all localization filters introduced so far are based on particle filters, an alternative approach is developed at the moment based on a Multi-Hypotheses Unscented Kalman filter. First results show significantly reduced runtime while still providing improved localization quality (see figure 4).



(a) Estimated positions and ground truth on the field.



(b) Errors in pose estimation.



(c) Localization runtime.

Fig. 4. Localization of Multiple-Hypotheses UKF compared to previous particle filter solution (which was used in RoboCup 2009). Both are running in parallel on the Nao using the same perception as input. Ground truth is provided by a camera mounted above the field.

3.3 Biped Walking and Motion Planing

Biped walking is significantly different from quadrupled locomotion and one of the major research topics related to humanoid robots. While the traditional approach to motion generation in robotics uses static playback of predefined motions, integration of sensor feedback can help to distinctly increase the movement's performance and especially its robustness. Therefore the current research of team *Nao Devils* focuses on different approaches to generate dynamic motions.

Motion generation can be divided in periodic motions, such as walking, and non-periodic motions, such as kicking motions. To define periodic motions our closed-loop approaches focus on the use of acceleration and foot pressure sensors to measure the stability of the executed motion. A path generator plans the desired trajectory by calculating suitable footstep positions to reach the desired walking motion. To generate the robot motions an inverted-pendulum model is used to generate gait walking patterns. A stable execution of the patterns is ensured by the help of ZMP measurement and an appropriate preview controller [9, 10]. The used approach to walking generation has proven to be successful during RoboCup 2009 Nao Standard Platform League and has been further improved and extended resulting in stable walking speeds up to $25\,cm/sec$.

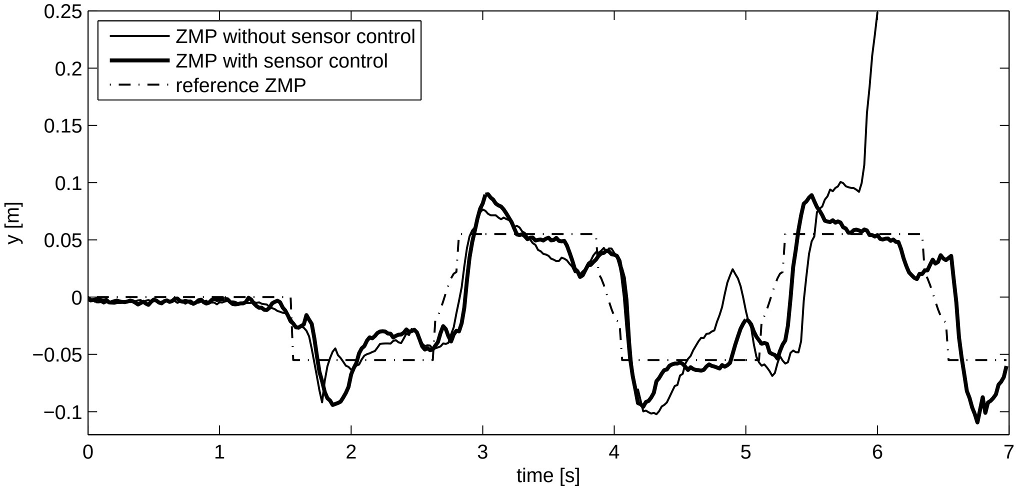


Fig. 5. The effect of sensor feedback control on a walking motion that was not calibrated for a real robot but for a simulation model. Without sensor control the real robot falls after a few steps, while with sensor control it is capable of compensating the differences of the internal model from the real robot's mechanical and physical properties.

To assure stability while reaching such fast walking speed requires high accelerations of body parts to keep the ZMP inside the support polygon. As a result the forces acting on the robot are no longer negligible at high speeds. Especially the movement of the swinging foot results in a momentum acting of the robot which can not always be supported by the ground friction. Thus the robot is likely to slide while moving which cannot be

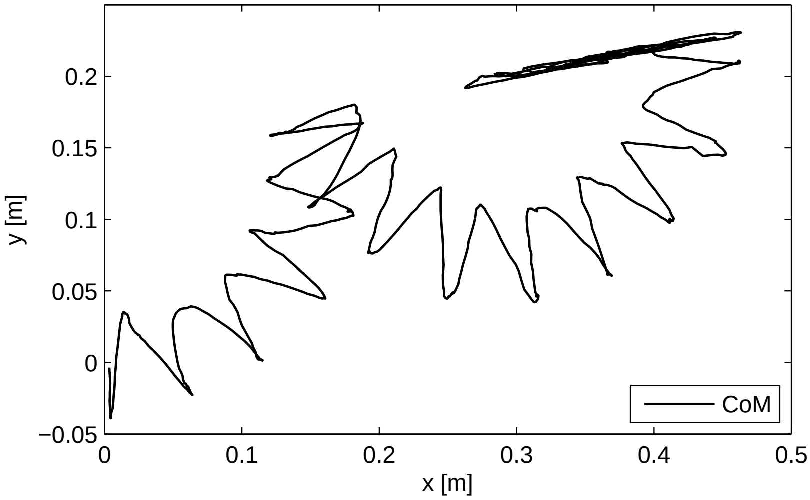


Fig. 6. Motion of the robot's center of mass while walking omnidirectional.

observed by any of the Naos internal sensors. Hence this slippage leads to an error of the odometry update and thereby resulting in an inaccuracy of the localization. To improve the estimation of this update error, team *Nao Devils* explored the application of external optical sensor to measure the slipping motion of the support foot during the single support phase of the walk [11]. Although the rules of the *Standard Platform League* prohibit modification of the hardware during the game, the gathered information of these sensors is still useful to calibrate the odometry correction factors.

Apart from using classic predefined special actions to plan non-periodic motions another focus is on different approaches to optimize those movements. Manual motion planning tends to be quite easy and reliably but the result is non-optimal in most cases. Thus a combine machine learning techniques with criteria defined by sensor information is approached to further optimize the usefulness and stability of motions. In addition utilizing sensor feedback to supervise robot stability during execution would allow for a more stable execution of motions. Therefore approaches to observe the execution of predefined motions with the help of a controller are a research focus of team *Nao Devils* [12].

3.4 Behavior Control

To autonomously solve tasks a robot must be capable to react to different inputs signals with the execution of suitable actions. The decision which action is chosen in a given situation is called *behavior control*. In the past the behavior language *XABSL* [13] has been successfully applied by different RoboCup teams including team *Nao Devils*. While defining simple behaviors and, due to the hierarchical approach, even designing complete behavior structures is an easy task using *XABSL*, developing and tuning complex behavior can be rather difficult. In addition *XABSL* behavior is generated beforehand by an expert user and thus is not capable of online-adaptation, for instance when a specific reaction always results in a failure.

While still utilizing *XABSL*, the last years behavior research focuses on applying different methods of *Computational Intelligence* to complement or substitute parts of the *XABSL* behavior. This study includes the application of fuzzy logic techniques to influence specific decisions otherwise statically implemented.

Despite being a very powerful tool to develop even the most complex behavior, experience of the past years has revealed that *XABSL* code can become quite complex and therefore hard to debug. This results mostly of the fact that *XABSL* combines both, strategical decisions and such involving motion planning. Even if the optimization of the walking commands with the help of *CI* methods such as fuzzy logic simplifies the expert tuning, the code itself still remains hard to debug.

Following the concept of detaching complex motions, such as kicking motion, by the means of special actions, team *Nao Devils* mimics this approach with the help of special walk commands. This is done by replacing the usual *XABSL* motion planning, utilizing speed vectors, with *go to* commands handled by the walking engine, greatly reducing *XABSL* code complexity. In addition tasks such as approaching specific position can be handled more precisely by placing the footsteps in the exact corresponding positions by the walking engine.

Although online-learning during games is far from being possible utilizing the given hardware, an adaptable behavior gives the opportunity to automatically optimize decisions for specific tasks. Machine learning approaches offer such features and hence are potentially interesting to apply to RoboCup behavior control. Current research focuses on the exploration to what extend a combination of behavior networks [14] and expert demonstrated learning can lead to better results than manually designed solutions.

4 Conclusion and Future Work

The main focus this year has been on developing new behavior strategies and improving vision, localization and motion. While the current walking speed is still too slow for example compared to the Humanoid League, faster speeds are limited to some degree by the hardware robustness of the Nao. The current walking approach is both dynamically stable, to some degree independent of ground properties like the carpet's smoothness, and has the potential for higher speeds.

Future work will concentrate on developing means to ease, improve, and possibly dispose of on-site calibration needs such as color calibration or motion parameter adaptations.

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