

# NAO-Team Humboldt 2010

## The RoboCup NAO Team of Humboldt-Universität zu Berlin

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### 1 Introduction

The NAO-Team Humboldt was founded at the end of 2007 and consists of students and researchers working at the Humboldt-Universität zu Berlin, coming from a number of different countries during the last years, in particular from Germany, Russia, Egypt, China, Iraq, and Iran.

We have a long tradition within RoboCup by working for the Four Legged league as a part of the GermanTeam in recent years. Thus, we could use some concepts and ideas from the GT-platform. The software architecture was written totally new. Additionally, we developed several tools such as RobotControl and MotionEditor for testing, debugging or for creating new motion nets.

We started with NAOs in May 2008 and achieved the 4. place in the competition at Suzhou 2008. We achieved 3. place in technical challenge at Graz 2009. A short overview about our implementation is given in section 2.

Our general research fields include agent oriented techniques and machine learning with their applications to cognitive robotics. As our record shows, our results are recognized outside RoboCup as well. In connection with the NAOs we investigate especially

- Relationships between simulated and real robots (section 3)
- Flexible motions using sensor feedback (section 4)
- Perception using Constraint based techniques (section 5)
- Gesture recognition (section 6)

Our investigations concerning simulation and reality have a special focus on 3D Simulation League. We plan to participate in both, Standard Platform League and 3D Simulation League with a common core of our program. Therewith, we hope to foster the cooperation between the two leagues and to improve both of them.

### 2 Implementation Outlines

Since the Humboldt-Universität has a long history in RoboCup, there is a lot of experience and already existing code (C++), especially from the GermanTeam with its module based architecture. Our code is divided into a part which is independent of the environment, i.e., the Core, which can run in any environment, and a specific part, which is applied to the particular platform. Besides the real robot we use Webots and SimSpark (3D Simulation league), the common core allows for uncomplicated usage of code in the simulation, too, cf. section 3. Debugging code can be switched on/off during runtime. Debug results are transferred over the network and monitored/visualized using RobotControl, a robot data monitoring and debugging tool, which is implemented in Java to be used on arbitrary platforms.

Basic image processing as color classification is performed using a 80x60 pixel grid. Object detection (ball, goals, lines, robots) applies classical methods, e.g., region growing. The camera matrix is computed by the kinematic chain (alternative approaches using constraints are under investigation, cf. section 5). Constraints are already used for navigation and world model as well as particle filters. A Kalman filter is applied to generate a local ball model. Global ball positions are communicated between players to coordinate team behavior.

Motions are implemented by keyframe techniques and inverse kinematics. Keyframe nets were developed through teaching and hand coding with the help of our motion editor framework. For parameterized dynamic motions as omnidirectional walks and kicks we use and investigate inverse kinematics and the sensor feedback cf. section 4.

Behavior is executed through a hierarchical state machine, known as XABSL (Extensible Agent Behavior Specification Language) [1]. The behavior code generation was supported by the related editor, debugging, and visualization tools. It allows layered usage of different behaviors, from very low-level motions to high-level cooperative team skills. Each option in the behavior tree decides the running time of its direct active sub-options in case of being activated itself, though each one takes care of its own timing. Furthermore options have some internal state criteria, used as inter-option communication means, mainly utilized by sub-options and their super options. Each option can also have a possible transition condition, through which along with the option's state propagation, the active behavior-switching in any decision level can be safely accomplished.

### 3 Simulation and Real Robots

As a common experience, there are big gaps between simulation and reality, especially with regards to basic physics with consequences for low level skills in motion and perception. We investigate the relationships and possibilities for method and code transfer. Consequences can lead to better simulation tools, especially in the 3D Simulation League. We plan to participate in both, Standard Platform League and 3D Simulation League with the common core of our program. As stated already, therewith, we want to foster the cooperation between the two leagues and to improve both of them.

When compared to real Nao robots, some devices are missing in the SimSpark, as LEDs and sound speakers. On one hand, we added some devices, e.g., camera, accelerometer, to simulate the real robot. On the other hand, we can use a virtual vision sensor which is used in 3D simulation league instead of our image processing module.

The key point to success is narrowing the gap between simulation and reality. There are some researchers who have already tried to achieve this, but there are only few successful results so far. Our plan is to analyze data from sensors/actuators in simulation and from real robots at first and then to apply machine learning methods to improve the available model or build a good implicit model from the data of real robot.

So far, we have developed walking gaits through evolutionary techniques in a simulated environment [2, 3]. Reinforcement Learning was used for the development of dribbling skills in the 2D simulation [4], while Case Based Reasoning was used for strategic behavior [5, 6]. BDI-techniques have been investigated for behavior control, e.g., in [7, 8].

### 4 Flexible Motions

Fixed motions as keyframe nets perform well in a very restricted way and determinate environments. More flexible motions must be able to adapt to different conditions. There are at least two specifications: Adaption to control demands, e.g., required changes of speed and direction, omnidirectional walk, and adaptation to the environment, e.g., different floors. The adaptation of the kick according to the ball state and fluent change between walk and kick are another examples.

Different control commands can be satisfied by parameterized motions and by online calculations. For the latter, we investigate inverse kinematics. Adaptation to changing conditions requires feedback from sensors. We experiment with the different sensors of the NAO. Especially, adaptation to the visual data, e.g., seen ball or optical flow, is investigated. Problems arise from sensor noise and delays within the feedback loop.

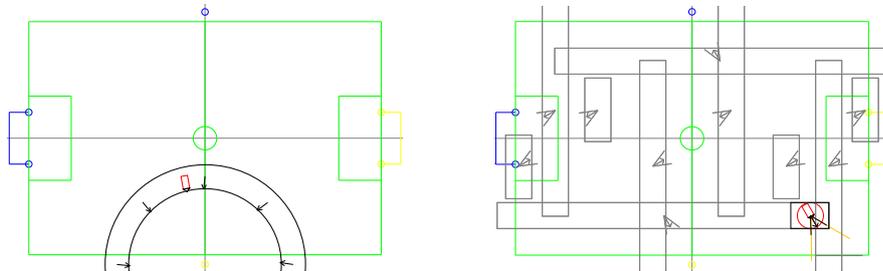
We have investigated different Optimization and Machine Learning approaches, as evolutionary approaches [9, 2] and recurrent Neural Networks [10] for Aibos and humanoid robots, and - as mentioned earlier - Reinforcement Learning (RL) with applications for the 2D simulation league [4]. Recently, another PhD thesis with focus on RL for humanoid robot walking is being written.

At present, some of our developed motions can be watched as videos on our web site <http://www.naoeamhumboldt.de/category/media/>.

## 5 Perception

We investigate the application of Constraint based techniques for navigation, and compare the approach to classical Bayesian approaches as Kalman filters and Monte-Carlo methods. Kalman filters make certain assumptions about the environment (linearity of the model, Gaussian noise), Monte-Carlo methods as particle filters are restricted by high computational demand and thus, low dimensionality. We have investigated these methods under various perspectives in the previous years [11–18] including missing information [19]. Constraint techniques have to handle inconsistent data, but can be advantageous whenever ambiguous data is available [20]. They are computationally cheap using interval arithmetic, and they can be easily communicated allowing for cooperative localization [21–26].

Classical approaches are prone to error propagation (e.g. from camera matrix over self localization to global positions of other objects). Using constraints, all related parameters (e.g. kinematic chain, camera matrix, positions) can be connected by related constraints and the common solution can be calculated by propagation techniques, [27–29].



**Fig. 1.** Both figures show constraints, generated from percepts (pictures show the algorithm on an Aibo field). Left: a circular constraint as generated from flag percepts. Right: a line constraint, generated from line percepts.

Constraints are built by image percepts from flags, goals, lines and other objects (even dynamical ones like ball and other players) [23]. They are able to deal with missing information [19] as well. Other sensors such as joint sensors lead to constraints for the camera matrix. Further constraints can use communicated information and past information, e.g., object speed. Each information can be used to constrain the related parameters. The shape of the constraint is determined by the type of information and the expected sensor noise. We use constraint propagation (interval arithmetics) for further restrictions of possible values of the parameters, as for positions [27, 30, 29].

Recent investigations and experiments deal with the treatment of inconsistencies (e.g. by ghost percepts) and further increase of performance. Furthermore we developed and tested a constraint-based player model.

## 6 Gesture Recognition

In order to realize intuitive interaction and communication between humanoid robots and people, we developed a system that can visually recognize dynamic arm gestures performed by a person [31]. The algorithm has been implemented on the NAO using URBI and an optimized version of our original algorithm is tested with a camera-based computer system [32]. Both supervised and unsupervised learning of gestures has been tested. Methods include adaptive color-based tracking of face and hands [33], Viola-Jones detector, and Hidden-Markov Models. The algorithms could also be extended to realize gesture-based robot-robot interaction. The results of these studies might be interesting for communication between in RoboCup in the near future.

## References

1. Löttsch, M., Risler, M., Jünger, M.: Xabsl - a pragmatic approach to behavior engineering. In: Proceedings of IEEE/RSJ International Conference of Intelligent Robots and Systems (IROS), Beijing, China (October 9-15 2006) 5124-5129
2. Hein, D., Hild, M., Berger, R.: Evolution of biped walking using neural oscillators and physical simulation. In: RoboCup 2007: Robot Soccer World Cup XI. Lecture Notes in Artificial Intelligence, Springer (2007)
3. Hein, D.: Simloid – evolution of biped walking using physical simulation. Diploma thesis, Humboldt-Universität zu Berlin, Institut für Informatik (2007)
4. Uc-Cetina, V.: Reinforcement Learning in Continuous State and Action Spaces. PhD thesis, Humboldt-Universität zu Berlin (2009)
5. Burkhard, H.D., Berger, R.: Cases in robotic soccer. In Rosina O. Weber, M.M.R., ed.: Case-Based Reasoning Research and Development, Proc. 7th International Conference on Case-Based Reasoning, ICCBR 2007. Lecture Notes in Artificial Intelligence, Springer (2007) 1-15
6. Berger, R., Lämmel, G.: Exploiting Past Experience. Case-Based Decision Support for Soccer Agents. In: Proceedings of the 30th Annual German Conference on Artificial Intelligence (KI'07), Springer (2007)
7. Berger, R.: Die Doppelpass-Architektur. Verhaltenssteuerung autonomer Agenten in dynamischen Umgebungen (in German). Diploma thesis, Humboldt-Universität zu Berlin, Institut für Informatik (2006)
8. Burkhard, H.D.: Programming Bounded Rationality. In: Proceedings of the International Workshop on Monitoring, Security, and Rescue Techniques in Multiagent Systems (MSRAS 2004), Springer (2005) 347-362
9. Düffert, U.: Vierbeiniges Laufen: Modellierung und Optimierung von Roboterbewegungen (in German) (2004) Diploma thesis.
10. Hild, M.: Neurodynamische Module zur Bewegungssteuerung autonomer mobiler Roboter (in German). PhD thesis, Humboldt-Universität zu Berlin (2007)
11. Hoffmann, J.: Proprioceptive Motion Modeling for Monte Carlo Localization. In: RoboCup 2006: Robot Soccer World Cup X. Lecture Notes in Artificial Intelligence, Springer (2007)
12. Jünger, M.: Bearing-only localization for mobile robots. In: Proceedings of the 2007 International Conference on Advanced Robotics (ICAR 2007), Jeju, Korea,. (August 2007)
13. Jünger, M.: Self-localization based on a short-term memory of bearings and odometry. In: Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2007), San Diego (October 2007)
14. Jünger, M., Mellmann, H.: Memory-based state-estimation. *Fundamenta Informaticae* **85**(Number 1-4) (2008) 297-311

15. Jüngel, M., Mellmann, H., Spranger, M.: Improving vision-based distance measurements using reference objects. In Visser, U., Ribeiro, F., Ohashi, T., Dellaert, F., eds.: RoboCup 2007: Robot Soccer World Cup XI. Volume Volume 5001/2008 of Lecture Notes in Computer Science., Springer Berlin / Heidelberg (2007) 89–100
16. Jüngel, M., Risler, M.: Self-localization using odometry and horizontal bearings to landmarks. In Visser, U., Ribeiro, F., Ohashi, T., Dellaert, F., eds.: RoboCup 2007: Robot Soccer World Cup XI. Lecture Notes in Artificial Intelligence, Springer (2007)
17. Mellmann, H., Jüngel, M., Spranger, M.: Using reference objects to improve vision-based bearing measurements. In: Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems IROS 2008, Acropolis Convention Center, Nice, France, IEEE (22–26 Sept. 2008) 3939–3945
18. Mellmann, H.: Active landmark selection for vision-based self-localization. In: Proceedings of the Workshop on Concurrency, Specification, and Programming CS&P 2009. Volume Volume 2., Kraków-Przegorzaly, Poland (28–30 September 2009) 398–405
19. Hoffmann, J., Spranger, M., Göhring, D., Jüngel, M., Burkhard, H.D.: Further studies on the use of negative information. In: Proceedings of the 2006 IEEE International Conference on Robotics and Automation (ICRA) IEEE. (2006)
20. Göhring, D., Mellmann, H., Gerasymova, K., Burkhard, H.D.: Constraint based world modeling. *Fundamenta Informaticae* **85**(Number 1-4) (2008) 123–137
21. Göhring, D.: Distributed object modeling using object relations in dynamic environments. In: Proceedings of Concurrency, Specification and Programming (CS&P 2006). (2006)
22. Göhring, D., Hoffmann, J.: Sensor Modeling Using Visual-Object Relation in Multi Robot Object Tracking. In: RoboCup 2006: Robot Soccer World Cup X. Lecture Notes in Artificial Intelligence, Springer (2007)
23. Göhring, D., Burkhard, H.D.: Multi robot object tracking and self localization using visual percept relations. In: Proceedings of IEEE/RSJ International Conference of Intelligent Robots and Systems (IROS), pages 31–36, IEEE (2006)
24. Göhring, D.: Cooperative object localization using line-based percept communication. In Visser, U., Ribeiro, F., Ohashi, T., Dellaert, F., eds.: RoboCup 2007: Robot Soccer World Cup XI. Lecture Notes in Artificial Intelligence, Springer (2007)
25. Göhring, D., Burkhard, H.D.: Cooperative world modeling in dynamic multi-robot environments. *Fundamenta Informaticae* **75**(1–4) (2007) 281–294
26. Göhring, D.: Constraint Based World Modeling for Multi Agent Systems in Dynamic Environments. PhD thesis, Humboldt-Universität zu Berlin (2009)
27. Göhring, D., Mellmann, H., Burkhard, H.D.: Constraint based belief modeling. In Iocchi, L., Matsubara, H., Weitzenfeld, A., Zhou, C., eds.: RoboCup 2008: Robot Soccer World Cup XII. Lecture Notes in Artificial Intelligence, Springer (2008)
28. Göhring, D., Mellmann, H., Burkhard, H.D.: Constraint based object state modeling. In Herman, B., Libor, P., Miroslav, K., eds.: European Robotics Symposium 2008. Volume Volume 44/2008 of Springer Tracts in Advanced Robotics., Prague, Czech Republic, Springer Berlin / Heidelberg (2008) 63–72 This volume (EUROS 2008).
29. Göhring, D., Mellmann, H., Burkhard, H.D.: Constraint based world modeling in mobile robotics. In: Proc. IEEE International Conference on Robotics and Automation ICRA 2009. (2009) 2538–2543
30. Göhring, D., Mellmann, H., Burkhard, H.D.: Constraint based localization on a humanoid robot. In: Proceedings of the Workshop on Concurrency, Specification, and Programming CS&P 2008. (2008)
31. Bertsch, F., Hafner, V.: Gesture recognition as a prerequisite of imitation learning in human-humanoid experiments. In Lola Canamero, Pierre-Yves Oudeyer, C.B., ed.: Proceedings of EpiRob09, Ninth International Conference on Epigenetic Robotics, Lund University Cognitive Studies, 146 (2009) pp. 197–198
32. Bertsch, F., Hafner, V.: Real-time dynamic visual gesture recognition in human-robot interaction. In: Proceedings of Humanoids 2009, 9th IEEE-RAS International Conference on Humanoid Robots. (2009) to appear.
33. Bertsch, F.: Visuelle Gestenerkennung zur Interaktion zwischen Mensch und Roboter (in German). In: Proceedings of 15. Workshop Farbbildverarbeitung 2009, Berlin, GfAI (08.-09.10.2009 2009)