Berlin United - Nao Team Humboldt 2015

Heinrich Mellmann, Benjamin Schlotter, Marcus Scheunemann, Tobias Hübner, Schahin Tofangchi, Thomas Krause, Claas-Norman Ritter, Steffen Kaden, Hans-Dieter Burkhard, and Verena Hafner

Adaptive Systeme, Institut für Informatik, Humboldt-Universität zu Berlin, Berlin, Germany
`http://naoth.de`

Fig. 1. *NaoTH* at competitions in 2014, from left to right: Iran Open, German Open and RoboCup.

1 Introduction

Nao Team **H**umboldt (*NaoTH*) is part of the Adaptive Systems group at the Humboldt-Universität zu Berlin headed by Prof. Verena Hafner and a member of the joint research group "Berlin United", together with the RoboCup team *FUmanoids*[1] from the Freie Universität Berlin. The team mainly consist of graduate and undergraduate students and is closely involved in the teaching process. *NaoTH* has a long tradition within the RoboCup. Established at the end of 2007 at the former AI research lab headed by Prof. Hans-Dieter Burkhard, *NaoTH* is the successor of the *Aibo Team Humboldt*, which won the world championship three times in the *Four-Legged League* as part of the *GermanTeam*. Since its foundation the team participates in every RoboCup and numerous local events in the *Standard Platform League (SPL)* and *3D Simulation League (S3D)*. It is actively contributing to the RoboCup community by publishing related research and organizing workshops.

Since its foundation *NaoTH* annually participates in the **RoboCup** world championships and, with a few exceptions, at **German Open** and **Iran Open**. Here is a brief overview of our achievements at these competitions including a

[1] *FUmanoids* is a RoboCup Humanoid KidSize team and located at the Freie Universität Berlin.

number of some other local events. At the RoboCup world championship 2014 in Brazil we reached the **quarterfinals** in the *SPL* and were selected as one of the top 5 players in the drop-in competition who constituted the *all-star team*. At the IranOpen we won **2nd place** in the main competition in the *SPL* and **1st place** in the scientific challenge with our contribution to local modeling (cf. section 5). In the world cup 2012 in Mexico we won the technical challenge with an extension for the *SimSpark* Simulator, used in *S3D*. In 2011 we won the Iran Open competition in *SPL*. At the very first *SPL* competition in 2008 in China we reached the semifinals. In 2010 and 2011 we quite successfully participated in the 3D simulation league with our *SPL* code. In 2010 we won the German Open and the AutCup competitions and achieved the second place at the RoboCup world championship in Singapore. In 2011 we could reach the semifinals at Iran Open and German Open. Please refer to our web page for the full list of our achievements.

Besides a wide participation in RoboCup events our team is actively striving to contribute to the RoboCup community and its progress. Our primal focus is thereby on communication and cooperation between different teams within *SPL* as well as across different leagues. Organization of workshops, code releases and efforts for cooperation across different leagues are described in section 2 in more detail. Our research interests spread across the whole spectrum required for a successful participation in RoboCup ranging from software architecture for autonomous robots, basic motion control, vision, perception, and modeling to high level planning. The results are regularly published at international workshops and conferences. In the following sections we summarize our recent efforts towards software architecture for an autonomous agent (section 3); improvement of the robot's motion abilities (cf. section 4); more stable and versatile perception (section 5). In section 6 gives a brief overview over related research projects reaching beyond the scope of RoboCup.

2 General Contribution to the Community

NaoTH has been contributing to the RoboCup community for more than ten years in various ways. The exchange of ideas and experiences is an important aspect which we try to foster by organizing workshops, courses etc.

Robotic Workshops (RoBOW). **Ro**boCup **B**erlin **O**pen **W**orkshop (*RoBOW*) is a successful series of workshops with the focus on giving the participants the time and the space to exchange ideas, work together and make tests, which usually comes short at competitive RoboCup events and scientific conferences. Originated in 2010, it started from a number of small workshops in Berlin. Due to large interest among the teams of the SPL and Humanoid KidSize leagues we hosted a series of large workshops RoBOW'11.1, 11.2 and RoBOW'12.1, 12.2, 12.3 with more than 10 teams and 40 participants. Several major workshops with international participation have been organized by other SPL teams around Germany: RoBOW'13.1 and 14.1 in Dortmund, RoHOW'14.2 in Hamburg and upcoming RoBOW'15.1 in Bremen as well as a number of smaller events inspired by the idea of RoBOW. Further workshop information can be found at our homepage `http://robow.de`.

RoboCup Projects. In the past years *NaoTH* was awarded several grants for projects promoting RoboCup. In particular we have developed a *software framework for autonomous robots* and an *extension for SimSPark* (cf. section 3).

Berlin United. *NaoTH* formed a conjoint team with the FUmanoids in 2011. This fusion was a result of a long-standing cooperation between our teams which has rapidly grown in the recent years including joint test games and workshops. We hope to achieve strong synergy effects for our efforts within RoboCup and closer cooperation between our leagues.

Courses. Our team is actively involved in the teaching process within our department. SPL and Simulation 3D (S3D) scenarios are used for demonstrations and practical exercises in the related courses (AI, Cognitive Robotics, Human Robot Interaction, Embodied Artificial Intelligence). Special intensive workshops for robotic beginners took place in universities and schools. Beyond that we offer special courses and seminars on RoboCup which involve students actively in the work within our team. We are also offering possibilities for Bachelor-, Master- and PhD theses related to projects within our team.

Code Release. In 2014 we published our code base and a team report, which can be found under the following links:

Code:	`https://github.com/BerlinUnited/NaoTH`
Documentation:	`https://github.com/BerlinUnited/NaoTHDoc/wiki`
Report:	`http://naoth.de/papers/NaoTH14Report.pdf`

3 Infrastructure

Over the years the infrastructure of our project has evolved into a stable and flexible ecosphere of tools and libraries allowing a continuous and steady development of our project. In particular it allows new members an easy and quick start with the project, which is a crucial aspect since our team is mainly driven by students of different levels. This section gives a brief overview over

Architecture. An appropriate architecture (framework) is the base of each successful heterogeneous software project. AI and robotics related research projects are usually more complicated, since the actual result of the project is often not clear. A strong organization of the software is necessary if the project is involved in education. Our software architecture is organized with the main focus on modularity, easy usage, transparency and easy testing. Please refer to our recent publication [17] for more details.

SPL simulator. *SimSpark*, the physical 3D simulator used by the S3D league, has been adapted and extended to suit the needs of the SPL. It simulates the environment of SPL including the basic game rules and allows the use of virtual vision as in 3D simulation. This allows to perform isolated experiments on low level, e.g., image processing, and also on high level, e.g., team behavior. This simulator can be downloaded from our Berlin United repository on *github*[2].

Simple Soccer Agent. We developed and published a simple framework for an easy start in the 3D simulation league, downloadable from our website[3].

RoboNewbie. Another approach for educating basic robotic skills is RoboNewbie. The Java framework is based on SimSpark and was successfully used within several workshops

XABSL Editor. The *XabslEditor*[4] is a graphical editor for the "Extensible Agent Behavior Specification Language" XABSL[5] which was developed by our team several years ago. It is implemented in Java and numerous teams around the world are using XABSL together with our *XabslEditor*.

4 Dynamic Motion.

Since the beginning of the team in 2007 we are working on flexible and stable motion capabilities for the robot. This section briefly summarizes our most recent efforts.

Neural Walk. We are experimenting with alternative approaches for motion generation on Nao. Inspired by the experiences of the related research group *NRL*[6] we implemented a walking algorithm based on a Neural Network. In our first experiments the neural approach used 1/3 less energy compared to our current walk.

Walk and Dynamic Step Control. We implemented a stable and flexible onmidirectional walk based on inverse kinematic and Linear Inverted Pendulum. The center of mass is controlled based on a preview of the future steps and actively stabilized based on the inertial sensors. This allows us to precisely control the steps, i.e., to approach the ball with the specified foot, and change the basic relation between the feet on-line, e.g., to realize a clown-walk. A special feature of our walk is the ability to alter the foot trajectory of a particular step, which can be used to realize sidekicks which are fluently executed during the walk.

[2] SPL Simulator source code and Ubuntu package: `https://github.com/BerlinUnited/SimSpark-SPL`

[3] `http://www.naoteamhumboldt.de/en/projects/simple-soccer-agent`

[4] *XabslEditor* is available at `http://www.naoth.de/en/projects/xabsleditor`

[5] `http://www.xabsl.de`

[6] `http://www.neurorobotik.de`

Dynamic Kick. Our dynamic kick is able to adapt on-line to the changes of the desired kicking direction as well as to the moving ball. For detailed description of the implementation, please refer to [20,16]. Videos showing some experiments performed on the real robot can be found on our homepage.

5 Perception and Modeling

One of our major research topics is world modeling. In particular, we consider it as being closely connected to perception and motion control, i.e., a good world model depends on active exploration of the environment (active attention control) and the adaptive perception which focuses on the information currently needed (passive attention control).

Adaptive Object Recognition. Although, this is one of the oldest topics in RoboCup, it is still far away from being solved. Currently we are working on dynamic recognition of the colors and detection of the objects based on geometrical features, to make the perception more independent from lighting conditions.

Local Modeling. Many tasks can be solved using only partial information like local spatial relations between objects. For example, the question whether the ball is inside a penalty area can be resolved by observing its spatial relation to the lines defining the penalty area. This might be more stable and require less computational effort compared to a global model. In our recent effort towards this idea we implemented a Multi-Hypothesis Goal Model providing a more stable representation of the goal regarding false detections and poorly calibrated kinematic chain. The results from this study have been published in [14,18].

Local Obstacle Model. As part of the local modeling we are working on local obstacle models, e.g., an obstacle model centered around the ball. Thereby, the obstacles, e.g., opponents around the ball are modeled. This view allows for an easier handling of ball-fighting situations.

Global Modeling. A global situation model consists of a network of local models connected by relations between them. This approach will allow for partial updates, pointing attention to some important parts of the model, e.g., a line, late integration of inconsistent information, e.g., a perceived line which does not fit to the actual state of the world is stored into a separate local model and maybe reused later. Another important factor is the treatment of errors. Classical probabilistic approaches usually do not distinguish between *sensor noise*, *false detections* and *ambiguity of observations* as qualitatively different sources of errors. We believe, that treating them separately may lead to much more stable results, e.g., sensor noise is modeled by local models and ambiguity is resolved by the global world model. These principle has been implemented and tested in case of the goal model (cf. [18]).

Constraint Self-localization. In the past years we have investigated constraint based techniques for self localization as alternatives to classical Bayesian approaches. Sensory input and prior knowledge provide spatial constraints for the position of the robot. Based in this, the localization problem is formulated as a constraint satisfaction problem, which can be solved by constraint propagation. Constraint based techniques can be advantageous while handling ambiguous information, e.g., unicolored goals, as well as integrating redundant data. They are computationally cheap using interval arithmetic, and they can be easily communicated allowing for cooperative localization. A comprehensive overview of our work can be found in [13,11,6,3,4,5].

Strategic positioning of robots using Voronoi diagrams. Strategic positioning is a decisive part of the team play within a soccer game. In most solutions the positioning techniques are treated as an inseparable constituent of a complete team play strategy. We propose an approach for strategic positioning allowing for flexible formulation of arbitrary strategies. Based on the conditions of a specific strategy, the field is subdivided in regions by a Voronoi tessellation and each region is assigned a weight. Those weights influence the calculation of the optimal robot position as well as the path. A team play strategy can be expressed by the choice of the tessellation as well as the choice of the weights. This provides a powerful abstraction layer simplifying the design of the actual play strategy. In [8] we present an implementation of an example strategy based on this approach and analyze the performance in simulation. We also provide a comprehensive overview of related work within RoboCup.

6 Further Related Research

This section summarizes some of the related research projects outside of RoboCup.

Grasping with additional tactile Sensors. Human grasping integrates a lot of different senses. In particular, tactile sensing is very important for a stable grasping motion. When we lift a box without knowing what is inside, we do it carefully using our tactile and proprioceptive senses to estimate the weight and thus, the force necessary to hold and to lift this box. We have implemented an adaptive controlling mechanism which enables a robot to grasp objects of different weight. Thereby, we only use the proprioceptive sensors like positions and electric current at the joints and additional force sensors at the end-effectors providing the *Nao* with tactile feedback (cf. [15,12])

Attentional Models. The skill of focusing ones attention to a certain aspect of the environment and excluding others is an important way of detecting the current context and reducing processing and memory load. Two agents can also have a joint attention [9]. In experiments with the humanoid robot Nao, an attentional model together with an Ego-sphere was implemented and tested during a human-robot interaction experiment [2]. In RoboCup, this skill allows to quickly find salient regions, e.g. other players moving or the ball.

Body Maps and Pointing. We performed random body babbling experiments on the Nao, where the Nao learned the relationship between a certain arm posture and the visual information for seeing its own hand [19]. Using an internal simulation, this could then be applied to moving the hand to a desired position in space without the need of any inverse kinematics [1]. In a second experiment, we showed that using this technique, the robot can perform pointing gestures to objects outside the field of reach based on the learned mapping [7]. For RoboCup, this could help to adjust motions (e.g. kicking a ball) perfectly to the given robot hardware, and also to perform gestures for communication between the robots.

Behavior Recognition. For interacting with the other robots on the field it can be advantageous to detect movement patterns of the opponents and predict where they will walk to. The goal of the experiment was to detect the other robots visually and model their movement on the soccer field over time. This model was learned by different kinds of learning algorithms and their performance was compared to a simple speed based model. A lot of research questions are still open but it could be shown that even for a short prediction time the knowledge based learning could perform better than simply propagating the speed of the other robot [10].

Most Recent Publications (without technical papers)

1. Bodiroža, S., Stern, H.I., Edan, Y.: Dynamic gesture vocabulary design for intuitive human-robot dialog. In: Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction. pp. 111–112. HRI '12, ACM, New York, NY, USA (2012), `http://doi.acm.org/10.1145/2157689.2157710`
2. Bodiroza, S., Schillaci, G., Hafner, V.V.: Robot ego-sphere: An approach for saliency detection and attention manipulation in humanoid robots for intuitive interaction. In: Proceedings of the 11th IEEE-RAS Conference on Humanoid Robots. pp. 689–694 (2011)
3. Göhring, D.: Constraint based world modeling for multi agent systems in dynamic environments. Ph.D. thesis, Humboldt University Berlin (2009), `http://edoc.hu-berlin.de/docviews/abstract.php?id=30348`, [Online: Stand 2010-05-23T15:08:02Z]
4. 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)
5. 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. pp. 2538–2543 (2009)
6. Göhring, D., Mellmann, H., Gerasymova, K., Burkhard, H.D.: Constraint based world modeling. Fundamenta Informaticae 85(Number 1-4), 123–137 (2008), `http://iospress.metapress.com/content/2051310891588554/`
7. Hafner, V.V., Schillaci, G.: From Field of View to Field of Reach - Could Pointing Emerge from the Development of Grasping? In: Proceedings of the IEEE Conference on Development and Learning and Epigenetic Robotics (IEEE ICDL-EPIROB 2011), conference abstract in Frontiers in Computational Neuroscience (2011)

8. Kaden, S., Mellmann, H., Scheunemann, M., Burkhard, H.D.: Voronoi based strategic positioning for robot soccer. In: Szczuka, M.S., Czaja, L., Kacprzak, M. (eds.) Proceedings of the 22nd International Workshop on Concurrency, Specification and Programming (CS&P). CEUR Workshop Proceedings, vol. 1032, pp. 271–282. CEUR-WS.org, Warsaw, Poland (2013)
9. Kaplan, F., Hafner, V.V.: The Challenges of Joint Attention. Interaction Studies 7(2), 135–169 (Jan 2006)
10. Krause, T.: Erfahrungsbasierte Lernmethoden zur visuellen Trajektorienvorhersage humanoider Roboter . Diploma thesis, Humboldt-Universität zu Berlin, Institut für Informatik (2011)
11. Mellmann, H.: Active landmark selection for vision-based self-localization. In: Proceedings of the Workshop on Concurrency, Specification, and Programming CS&P 2009. vol. Volume 2, pp. 398–405. Kraków-Przegorzaly, Poland (28–30 September 2009), http://csp2009.mimuw.edu.pl/proc.php
12. Mellmann, H., Cotugno, G.: Dynamic motion control: Adaptive bimanual grasping for a humanoid robot. Fundamenta Informaticae 112(1), 89–101 (2011)
13. 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. pp. 3939–3945. IEEE, Acropolis Convention Center, Nice, France (22–26 Sept 2008)
14. Mellmann, H., Scheunemann, M.: Local goal model for a humanoid soccer robot. In: Szczuka, M., Czaja, L., Skowron, A., Kacprzak, M. (eds.) Proceedings of the Workshop on Concurrency, Specification, and Programming CS&P 2011. pp. 353–360. Białystok University of Technology, Pułtusk, Poland (September 2011)
15. Mellmann, H., Scheunemann, M., Stadie, O.: Adaptive grasping for a small humanoid robot utilizing force- and electric current sensors. In: Szczuka, M.S., Czaja, L., Kacprzak, M. (eds.) Proceedings of the 22nd International Workshop on Concurrency, Specification and Programming (CS&P). CEUR Workshop Proceedings, vol. 1032, pp. 283–293. CEUR-WS.org, Warsaw, Poland (2013)
16. Mellmann, H., Xu, Y.: Adaptive motion control with visual feedback for a humanoid robot. In: the Proceedings of the 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems. Taipei (2010)
17. Mellmann, H., Xu, Y., Krause, T., Holzhauer, F.: Naoth software architecture for an autonomous agent. In: Proceedings of the International Workshop on Standards and Common Platforms for Robotics (SCPR 2010). Darmstadt (November 2010)
18. Scheunemann, M.M., Mellmann, H.: Multi-hypothesis goal modeling for a humanoid soccer robot. In: Proceedings of the 9th Workshop on Humanoid Soccer Robots, 14th IEEE-RAS International Conference on Humanoid Robots (Humanoids), Madrid, Spain. (2014), http://www.ais.uni-bonn.de/humanoidsoccer/ws14/papers/HSR14_Scheunemann.pdf
19. Schillaci, G., Hafner, V.V.: Random Movement Strategies in Self-Exploration for a Humanoid Robot. In: Proc. of the Intern. Conf. on Human-Robot Interaction 2011. pp. 245–246 (2011)
20. Xu, Y., Mellmann, H.: Adaptive motion control: Dynamic kick for a humanoid robot. In: Dillmann, R., Beyerer, J., Hanebeck, U., Schultz, T. (eds.) Proceedings of the 33rd Annual German Conference on Artificial Intelligence KI 2010. Lecture Notes in Computer Science, vol. 6359, pp. 392–399. Springer Berlin / Heidelberg (2010), http://dx.doi.org/10.1007/978-3-642-16111-7_45