Berlin United - Nao Team Humboldt 2017

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Fig. 1. *NaoTH* in the outdoor competition area at the RoboCup 2016 in Leipzig. From left to right: Steffen Kaden, Benjamin Schlotter, Thomas Krause, Peter Woltersdorf, Heinrich Mellmann, Robert Martin, Philipp Strobel. Not in the image: Claas-Norma Ritter.

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 consists of graduate and undergraduate students and is closely involved in the teaching process.

[1] *FUmanoids* is a RoboCup Humanoid KidSize team located at the Freie Universität Berlin. As of spring 2017 FUmanoids have stopped their RoboCup activities.

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.

Besides a wide participation in RoboCup events our team is actively striving to contribute to the RoboCup community and its progress. Our major 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 some of our recent efforts towards software architecture for an autonomous agent (section 3); visual perception (section 4); decision process (section 6); improvement of the robot's motion abilities (cf. section 7).

For a more extensive overview over our recent work please refer to our team report [3].

2 RoboCup Involvment

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

Achievements. 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 recent achievements at these competitions including a number of some other local events.

At the RoboCup world championship 2016 in Leipzig, our team reached the **3nd place** in the outdoor competition and **quarterfinals** in the *SPL* indoor competition. At the RoboCup world championships 2015 in China and 2014 in Brazil we reached the **quarterfinals** in the *SPL*. At all three RoboCup competitions 2015, 2016 and 2017 we were selected as one of the top 5 players in the drop-in competition who constituted the *all-star team*.

At the local competition German Open 2017 in Germany we could reach the semifinals. We finished the SPL competition at the European Open 2016 with the **4th place**. In the *SPL* we won the **3nd place** at the German Open 2015 and Iran Open 2015. In 2014 we achieved the **2nd place** at the Iran Open.

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. Our recent code base and a team report [3] can be found under the following links:

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

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 some core aspects of our architecture and related projects.

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 [5] 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. The source code and Ubuntu package for the simulator is avaliable at:
`https://github.com/BerlinUnited/SimSpark-SPL`.

Simple Soccer Agent. We developed and published a simple framework for an easy start in the 3D simulation league, downloadable from our website:
`http://naoth.de/en/projects/simple-soccer-agent`.

RoboNewbie. Another approach for educating basic robotic skills is RoboNewbie. The Java framework is based on SimSpark and was successfully used within several workshops. Further information can be found at the RoboNewbie project page

`http://www.naoth.de/en/projects/robonewbie`

XABSL Editor. The *XabslEditor* is a graphical editor for the "Extensible Agent Behavior Specification Language" XABSL[2] 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*. *XabslEditor* is available at

`http://www.naoth.de/en/projects/xabsleditor`

4 Visual Perception

Green detection. In the past years, the colors, which encoded important features, have almost completely disappeared from the SPL game setup. Nevertheless, green remains a major feature. We developed a simple yet reliable color classifier which is used to identify green color in the images. The classification is done in the YUV space. Thereby, the key point is the division of the classification in two steps: (1) separate the pixels which do not carry enough color information, i.e., these which are too close to the gray axis in the UV-plane; (2) classify the color in the projection onto the UV-plane. Even with a fixed choice of parameters, the method has proven to be stable with respect to brightness, accounting, for example, for shadows. The parameters for the two steps can be determined automatically to accommodate changes in the color temperature. More details on the method can be found in the team report [3, Section 4.1].

Ball Detection. In 2015 the standard ball used in competitions changed to a black&white ball. Detection of such a ball in the SPL setup poses a considerable challenge. Our approach processes an image from the robot camera in two steps: find a small set of suitable candidates for a ball by a fast heuristic algorithm, and classifying the candidates with a more precise method. The candidates are detected as local maxima of a box approximation of Difference of Gaussians filter. The approximated filter can be calculated very fast with the help of the integral image. In our case the search is performed on scaled image $160px \times 120px$. The size of the considered box is estimated based on a reprojection of the ball size to the image at the particular point in image. This has shown to be an important key component for stable ball candidates. In the current implementation, the classification method is based on Viola-Jones with Haar-like features. A faster and more reliable classification method based on convolutional neural networks is part of current development. Refer to our team report [3, Section 4.7] for more details.

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

Field Features. Field lines and goals are detected based on gradient in the brightness channel. The local maxima in the brightness gradient typically occur at the edges, e.g., between field color and a field line. These changes have shown to be very stable regarding changes in the lightning conditions. Refer to [3, Section 4.2-4.6] for more details.

5 Situation Modeling

Perceptual information, extracted from sensory data, needs to be integrated over time to cover the times where no perception is available, e.g., the ball is out of sight, and to extract not directly observable aspects like own position on the field. Our efforts in this area focus on utilization of local information and exploration of the specific character of perceptual information at hand.

Probabilistic Compass [3, Section 5.2]. For geometric reasons, direction observations are more stable with respect to the sensory noise than distance estimations. To utilize this fact we use the orientation of the edges in the image to directly estimate the rotation of the robot on the field. The orientations of the edges are integrated and smoothed with a kernel histogram. Since most of the lines on the field are oriented in right angles, we can infer the rotation of the robot from the maximal values of this histogram up to the $\pi/2$ symmetry. The histogram is then directly used to update the particle filter estimating the global position of the robot.

Multi-Hypothesis Ball Model [3, Section 5.3]. We use a multi-hypothesis ball model where each hypothesis is realized as a extended Kalman filter. This allows to track several different ball perceptions at the same time. In particular, false positive detections result in short lived ball hypotheses and do not interfere with the tracking of the actual ball.

6 Simulated Action Selection

In the RoboCup environment, selecting the right action is often a challenging task. The outcome of a particular action may depend on a wide variety of environmental factors, such as the robot's position on the field or the location of obstacles. In addition, the perception is often heterogeneous, uncertain, and incomplete.

We utilize forward simulation as a versatile and extensible yet simple mechanism for inference of decisions. The outcome of each possible action is simulated based on the estimated state of the situation. The simulation of a single action is split into a number of simple deterministic simulations – *samples* – based on the uncertainties of the estimated state and of the action model. Each of the samples is then evaluated separately, and the evaluations are combined and compared

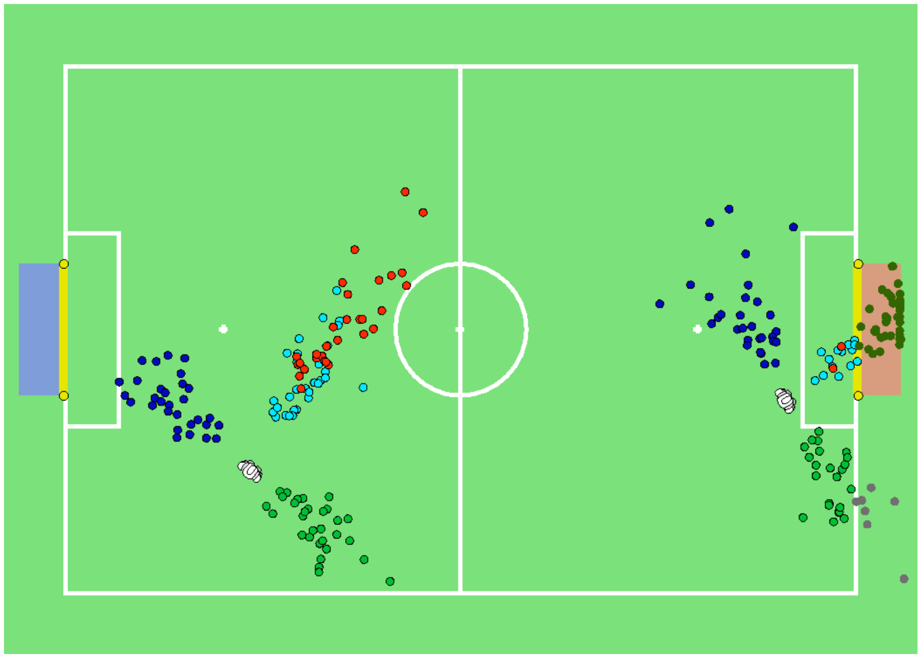

Fig. 2. Two example situations with kick simulation. Each possible kick direction is simulated with 30 samples (different colors correspond to different kicks). Left: the selected action is sidekick to the right – the other kicks are more likely to end up in a dangerous position for the own goal according to the potential field. Right: long kick is selected as the best action since it has the most samples result in a goal.

with those of other actions to inform the overall decision. This allows us to effectively combine heterogeneous perceptual data, calculate a stable decision, and reason about its uncertainty. Figure 2 illustrates the simulation process.

This approach is implemented for the kick selection task in the RoboCup SPL environment and is actively used in competitions. A detailed discussion of the simulation based approach applied to kick selection can be found in [2] together with experimental evaluation in the context of a real RoboCup competition.

7 Dynamic Motion.

Since the foundation of the team in 2007 we have been continuously working on flexible and stable motion capabilities for the robot. In the past, we developed a stable and fast walk and a dynamic kick which is able to adapt on-line to the changes of the desired kicking direction as well as to the moving ball [6,4]. Our recent focus has been on a dynamic step control which allows to realize omnidirectional kicks as special steps within a coherent step plan.

Our onmidirectional walk is based on inverse kinematic and Linear Inverted Pendulum. The center of mass is controlled based on a preview of the future steps

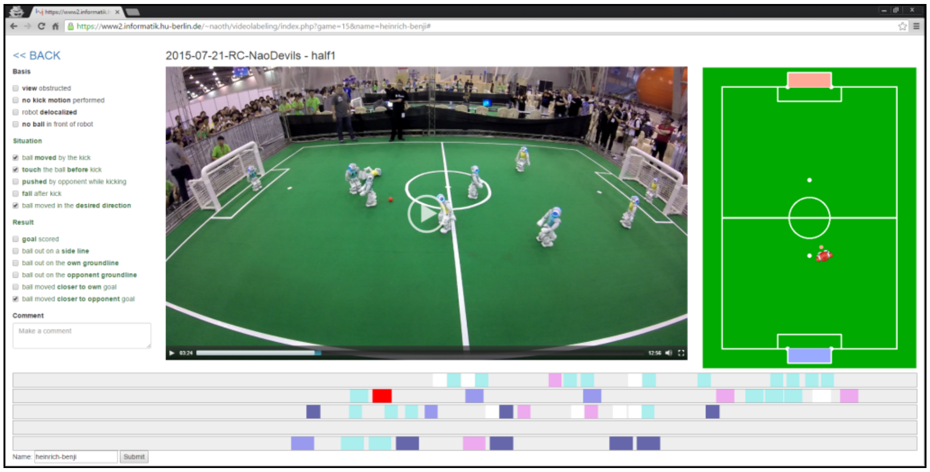

Fig. 3. Labeling interface used to annotate kick events regarding their quality. At the bottom are time lines for each of the robots. Different actions are represented by buttons on the time line with different colors. On the right the robots estimated state is visualized, i.e., estimation of its position, ball model and obstacles. On the left are three categories of labels capturing the quality of the action.

and actively stabilized based on the inertial sensors. This allows for a precise control of the step geometry, i.e., to approach the ball with the specified foot, and on-line change in the basic relation between the feet to realize different walk styles. 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.

8 Game Evaluation

RoboCup provides a unique *common test scenario* for evaluation and comparison of proposed methods and solutions in robotics, but its potential is not used to the fullest by far. Conducting games costs a tremendous amount of effort. The scientific outcome, however, is quite limited and often not very conclusive. In most cases only the final score of the games provides slim feedback about the performance of a team.

Collecting more data during the competition games could help to analyze the current state and uncover current problems, but also help to develop new solutions. In particular, analysis of the team behavior, like role change, require global synchronized data. It is much easier to collect this kind of data in a controlled experiment in a lab environment. However, the algorithms running on a robot tend to behave differently in the isolated environment of the lab compared to real conditions during a competition.

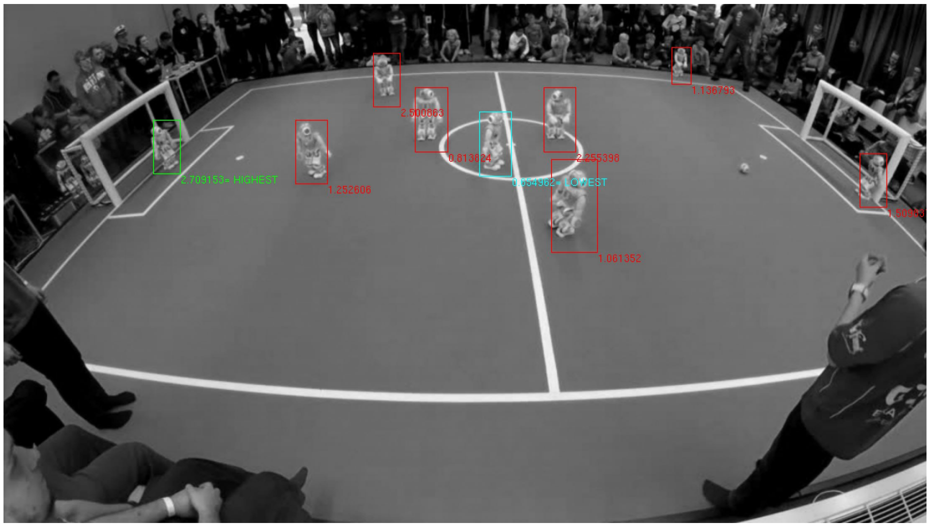

Fig. 4. Example of detected robots in a video recorded with a GoPro camera at the European Open 2016 in Eindhoven. Colored boxed illustrate the detected NAO robots with different confidence.

To address this issue, we are developing a toolbox (a set of tools) to support collection, organization and analysis of large amounts of RoboCup specific data enabling detailed analysis to promote data driven research and development in RoboCup. Crucial components of the toolbox are: (1) automatic recording of game videos synchronized with team communication and game control data; (2) infrastructure for recording of log files on each robot during the game; (3) synchronization of local (logs recorded by the robots) and global (game videos) information sources; (4) (semi) automatic mining in log files; (5) possibility for manual annotation of events in videos; (6) augmentation of videos with meta information (detected robots). This project is supported by the RoboCup Federation grant for League Developments 2017.

Figure 3 shows an example session of the annotation interface. In particular, it has been used to annotate different kick actions executed by our robots in the videos recorded during the games at the RoboCup in 2015. The kick events were automatically extracted from the log files recorded by the individual robots and aligned with the video. Thus the human annotator can simply click through the particular events and inspect them in a short time. The results were used to evaluate the performance of the kick decision algorithm and were published in [2].

Robot Detection in Videos is a diploma thesis project by Dominik Krienelke [1]. The robots are detected and tracked based on HOG features and SVM based classifiers. In addition, lines and goals will be used to localize the camera and estimate robots positions in global coordinates on the field. Figure 4 illustrates the current state of the robot detection approach.

9 Acknowledgements

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