

Bembelbots Frankfurt

ROBOCUP SPL TEAM AT GOETHE UNIVERSITY FRANKFURT

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1 Statement of Commitment

Team Bembelbots Frankfurt applies for participation in RoboCup 2013 SPL.

2 Team Bembelbots

The Joint Robotics Lab (JRL) is a joint project of three working groups of the Institut of Computer Science at Goethe University Frankfurt with the common goal to strengthen project orientated learning.

Early 2009 the JRL offered a working group, called RoboCup-AG. Within this group up to ten students started developing a robot behaviour using the Simulator Webots¹. Still in the same year this initial team founded the RoboCup team *Bembelbots Frankfurt*. The whole team was very motivated already from the beginning, met several times a week and everybody spent a lot of free time to perform strongly. This was necessary as right from the start, we decided to build our own framework from scratch and not to using already existent frameworks.

Due to fast satisfying results we participated in the RoboCup German Open, already in 2010. Since that time, we took part every year, gaining a lot of experience. We also obtained new practical and theoretical knowledge through visiting Open RoboCup Workshops in Berlin, through playing friendly matches and through exchanging knowledge with other teams. Thereby we made continuous good progress improving our framework. We implemented a robust vision, a satisfying self localisation, a dynamic behaviour, an own walk and much more. As a result of our efforts we got the chance to participate in the RoboCup World-Championship in 2012 and enjoyed the experience of our first in-

ternational competition very much.

During the years the team members changed but overall it grows continuously.



Figure 1: Team Bembelbots at the RoboCup German Open 2012 in Magdeburg.

Team Structure: Team leader of Bembelbots is Markus Meissner, a PhD student at the Electronic Design Methodology group at the Institute of Computer Science at the Goethe University Frankfurt. He has a good overview of the team members' activities and is very avid, especially in the development of behaviour and motion. Dr. Holger Friedrich, former head of the team, has left Goethe University, but still spends a lot of his free time for the team, especially in the areas vision, framework and software development methodology. Andreas Fürtig just finished his studies and wrote his diploma thesis on colour classification [2]. He will become a dedicated PhD student at the Joint-Robotics-Lab, soon. We have several senior students with strong contributions to the RoboCup. Tobias Weis has finished his diploma thesis on self localisation [3] and is still working continuously on improving the localisation.

¹<http://www.cyberbotics.com>

Christian Becker is currently working on his thesis on advanced line detection and scan-matching algorithms. Jens Siegl contributes technical knowledge and maintains the robots since the beginning of the project. Andreas Kehlenbach provided the infrastructure for XABSL and works on enhancing the walk-engine. Linda Luy and Vincent Michalski develop behaviours and Gerhard Ruscher concentrates on motions. Anna Reckers is the contact for mathematical problems. In addition we have several students who joined the RoboCup team in the last years. Konrad Zacharias, Eric Hanssen and Alexander Heun recently joined the team and are still searching for their field of interest.

3 Inventory of NAOs

We currently own six Nao V4 H21. As soon as a new version will be released, we will upgrade our NAOs. At the moment we do not intend buying any further robots.

4 Research Interests and Planned Activities

Focusing on computer vision development in the past years, the team Bembelbots made fast progress towards a reliable image based self localisation and therefore was also able to enhance the robots behaviour concerning game strategies.

In the last years the Visual Sensorics and Information Processing group concentrated on developing a robust vision system for the Nao. As an addition to Tobias Weis' diploma thesis, which dealt with object recognition, the optimization of backprojected line models and localisation in general [3], Christian Becker is working on his diploma thesis concerning positiontracking via scanmatching. The results of both works provide a lot of features needed for improving of the Multihypotheses Kalman Filter algorithm used for localisation.

The far higher performance of the Atom processor which is now integrated in the new Nao model, allows the reasonable usage of both cameras available. They provide a wider viewing range and further research may lead to stereo vision approaches, although recent evaluation showed that there are some technical limitations introduced by the Nao robot.

The forthcoming modification of the RoboCup field size led to considerations for making the field size scalable. Due to restricted space in the team's lab,

²<http://code.google.com/p/googletest/>

this project made fast progress and only slight modifications will be needed to successfully vary between any given sizes in the future.

Past experiences showed that using the provided NaoQi framework is not the optimal solution for competing against teams who detached their selves from this framework: faster walks and an overall improved agility are promising enhancements that legitimate the development of a self-made motion engine. Hence we started to disengage from the NaoQi and developed our own walk and are taking further steps to develop a completely self-contained motion engine.

5 Summary of Past Relevant Work

5.1 Software Framework

We developed our own software framework from scratch. It is written in C++ and consists of several modules. We compile against the NaoQi middleware, but have minimized the dependencies and wrapped library dependent calls. In addition to NaoQi we use external libraries OpenCV, libzip, Boost, and the XABSL engine. For the future we are planning to amplify the split-off of the NaoQi from our framework. The following paragraphs give an overview of the key aspects we focused on during the last three years.

5.1.1 Development Methodology

We have a strong focus on automated testing. Our base software framework is compiled and tested every time new code is checked into our source code management system. The unit test framework we use is googletest², and we check the coverage of our tests with a profiling tool gcov from the GNU Compiler Collection suite. Continuous Integration with Jenkins builds the whole framework on different systems everytime the codes is changed and ensures a stable framework at every time.

5.1.2 Locomotion

Walking Engine: Our first implementation for an own walk was based on [6]. As the paper proposed, we implemented a *closed-loop* walk.

However the stability of that walk was too bad for real walking. Our robots were able to dribble, but not to walk. Further tests and literature research guides us to an *open-loop* walk engine.

According to that and with the helpful assistance of Team Nao-HTWK of Leipzig we successfully developed a full parametrizable walk implementation

during the last year. A joystick control has been developed to comfortably setting the parameters.

Standing up: There are many reasons why a robot may fall over. In this case it is very important for the NAO to stand up again. Thus right at the time of our teams' initiation, we developed motions for standing up from different positions. These motions worked very safe but also very slow, so we enhanced them to become faster.

Goalie Move: Now that we have a reliable localisation, we implemented a dive for the goalkeeper that throws the Nao to the ground to cover much more space than with the previous one. After German Open 2011 we started developing a move to *pick up the ball* with the hands and throw or kick it away again. As soon as the rules are changed according to the ball holding rule, we will use this motion with our goalkeeper.

Kick: We implemented three kinds of kicks: front, back and side kick. The Nao chooses the type of kick due to the implemented behaviour. In addition, each kick is parametrizable, where the robot himself computes the right parameter from the ball position.

5.1.3 Cognition

Camera Like most teams, for a long time we used only one camera. Regarding the increasing field in 2013, it will become more necessary to have a far-reaching view. Seeing the goal at the end of the field is as important as seeing the ball directly in front of the robots' feet. That's the reason why we decided to use both cameras and we already implemented the usage.

Classification The cognition process is mainly split into two parts. In a first step, *colour classification* is applied to the high resolution image. Classification is based on a Gaussian model describing the statistics of the colour values. A fast implementation using Lookup Tables guarantees a processing rate in real time [1]. After this step, the environment is separated into 6 different colour classes, which can easily be processed in order to find important elements on the field. The classification step is very *robust to changes in illumination*, which typically appear in competitions or show events, and thus there is no need to calibrate the Lookup Table by hand before each game.

To deal with the new field dimensions, we decided to use both cameras of the Nao. Both images are

not processed in parallel, instead we toggle the cameras in each step to save computational power. Due to a high framerate of nearly 30 processed images per second, this means we classify 15 images of each camera per second.

To minimize cache-misses, which lead to a slower processing rate, the whole Lookup Table was also compressed [2]. A result image of the classification step can be seen in Fig. 2.

Detecting Objects Based on the fact that the colour-classification provides very good results, the subsequent object recognition modules work on binary images of each colour class of interest. Mainly histograms on this binary images are used to find objects of interest, like goals and balls. This method comes with the benefit of being very robust on a small number of misclassified pixel values. Besides simple geometry checks on the shape of the objects to be recognized, a feedback loop has been implemented relating the distance of an object to its dimension. After calibration of the robots, we achieved good results for distance measurements based on triangulation.

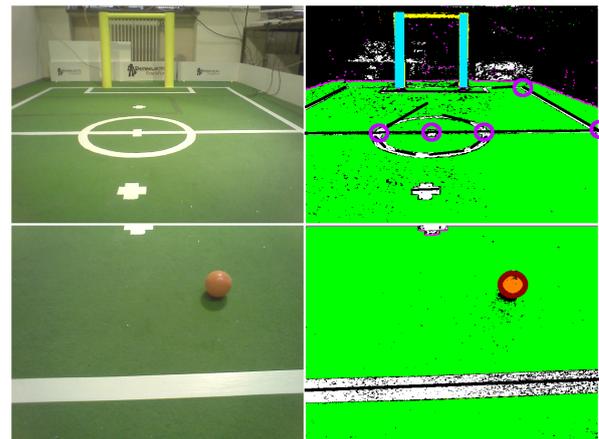


Figure 2: Result of the Dual Vision Module. *Left column:* Original Image (converted to RGB), *right column:* Classification of the input image with found vision results: A ball, yellow goalpoles and several corners, which then are processed by the localisation module.

Detecting Lines, Corners, and the Centre Circle

The colour classified images are scanned with horizontal and vertical scanlines to find green-white-green transitions. Currently we are developing a method, that not only takes colour into account and makes use of en- and decreases in the illumination channel of the *YUV*-image. The scanlines distance is adjusted based on the distance of image points projected to the ground-plane, such that the distance between scanned points on the ground is less than 5cm.

Detected line points will be connected to lines, and in a second step lines that match in space and orientation will be joined. These lines are then projected onto the ground-plane of the robot-coordinate-system. In this space, known geometrical relations between field lines are apply, easing the detection of then centre circle and the corners.

5.1.4 Localisation

During the past year our main focus of attention was the improvement of our localisation methods. The detection of lines, corners, the centre circle and poles (as explained above) are used for computing all likely positions of the robot in the world.

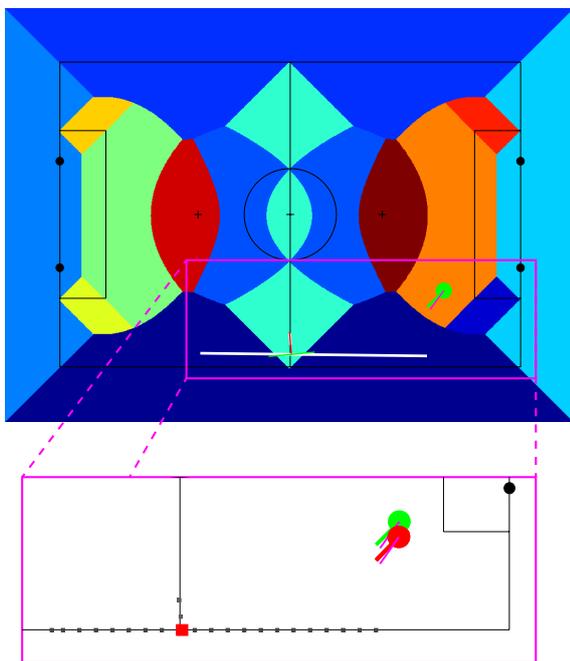


Figure 3: Top: The soccerfield underlayed with a voronoi map. Each colour corresponds to a fieldline. This map is used for lookup. White the detected fieldlines, projected to the ground at the believed robot position (green). Bottom: Magnified view after the Scan-Matching process. The grey dots represent the former detected lines. It is easy to see that the overlay is much better. Red is the corrected position on the field.

The more features detected in one picture or the more expressive the detected features are, the less positions are likely (a detected goal equals two likely positions on the field, where a single L-Corner yields eight possible positions). Every possible position calculated like this is a measurement for the Kalman filter. However, the benefit of different coloured goals is no longer existent and the feasibility of following more than just one track is a crucial constraint.

The additional symmetries introduced by two goals of the same colour implicate an increasing variety of robot positions for a single measurement. The increasing number of field players further decreases the possibility of detecting strong landmarks, so we implemented a Multi Hypothesis Kalman Filter and introduced two new measurements for breaking the symmetry.

The use of infrared emission by the goalkeeper aids to the localisation of field players by providing a strong hint about their orientation and about their field half (IR range is approx. 3m). Fused ball positions (especially with the goalkeeper) also provide useful information about the field half, and, in the case of a successfully fused team-ball, about their positions.

For cases where little information is available for localisation (e.g. only one line), we are developing a Scan-Matching approach based on [9] to provide some kind of local position estimation.

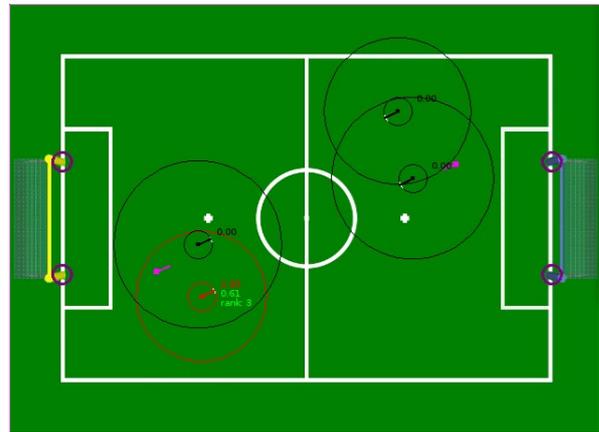


Figure 4: Live visualisation of the hypotheses of the kalman filter with according covariances. The direct result of the current measurement (goal) is shown in pink, the most likely hypothesis in red.

The detected field lines and other features will be matched to the known environment, given the position estimate. To minimize the lookup of which detected feature should be matched to which of the world we use a similar approach like [10]. This will allow position correction even with very little information. Fig. 3 shows an example.

5.1.5 Behaviour

Since our first participation in the German Open we have full support for the Game Controller and the Button Interface. At the beginning, we used hard coded finite state machines to control the behaviour. As our team has grown larger, we decided to divide the development into pure framework development and behaviour development. To get this working, we've chosen the Extensible Agent

Behaviour Specification Language (XABSL) as behaviour development language. We integrated the XABSL engine into our framework and implemented a wrapper class, to parse arguments from the framework to the behaviour and vice versa.

5.1.6 Scaleable field size

Based on the announcement to enlarge the field in 2013 we will no longer be able to construct a field in one of the institutes rooms. Therefore we re-structured all modules and external tools to utilize a centralized variable field definition. This also allowed the construction of a smaller, permanent field in one of our lab rooms.

5.2 Tools

Several tools have been developed in the last years, allowing us to debug and analyse the behaviour of our Naos. Those tools are written in Python, mainly for portability purposes. They work either with Linux, Windows and partly also on mobile phones (Android). *NaoDebug* is the main Application for debug the Robot, for example change camera parameters or receive live images. The current state of the XABSL FSM can be displayed graphically, as well as the current state of the world model of the robots and their global position in the world. This speeds up the whole development process, as errors are detected very early and easily.

Our old remote tool to control the robot for demonstration purposes was merged with *NaoDebug*. An old version of the remote (*NaoRemote*) is still available on the team home page [7].

Since all of our tools still use the connectivity of the NaoQi Middleware, we plan to implement an abstract connection layer to communicate with our robots over a standard TCP/IP Connection in the future.

5.3 Public Activities

Team Bembelbots is also very devoted to increase the awareness of the RoboCup initiative by organizing and taking part in public events.

Every year we are organizing different events for the high frequented Night of Science, since 2011 we are also part of the Computer Science Day and the Summer Festival of Goethe University. In 2012 the team carried out robotic classes for high-school level students participating in a summer school program provided by Goethe University. Several positive reviews in local and regional press documented the great success of our public activities³.

³<http://www.bembelbots.de/web/press/>



Figure 5: High-school students working with the Nao in a summer school.

5.4 Scientific Publications

Scientific publications [1], Diploma theses [2, 3], Bachelor theses [4, 5].

References

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