GermanTeam 2008

The German National RoboCup Team

David Becker[2], Jörg Brose[2], Daniel Göhring[3], Matthias Jüngel[3], Max Risler[2], and Thomas Röfer[1]

[1] Deutsches Forschungszentrum für Künstliche Intelligenz, Safe and Secure Cognitive Systems, Robert-Hooke-Str. 5, 28359 Bremen, Germany
[2] Fachgebiet Simulation, Systemoptimierung und Robotik, Fachbereich Informatik, Technische Universität Darmstadt, Hochschulstraße 10, 64289 Darmstadt, Germany
[3] Institut für Informatik, LFG Künstliche Intelligenz, Humboldt-Universität zu Berlin, Rudower Chaussee 25, 12489 Berlin, Germany.

`http://www.germanteam.org`
`germanteam@tzi.de`

1 Introduction

The GermanTeam participates as a national team in the RoboCup Four-Legged League since 2001. It currently consists of students and researchers from the Humboldt-Universität zu Berlin, the Universität Bremen, and the Technische Universität Darmstadt. After winning the technical challenge in 2003 and the world championships in 2004 and 2005, the team only reached place four in 2006. Therefore, a major overhaul of the whole software system was necessary in order to stand a reasonable chance in RoboCup 2007. With a new software architecture [1] the GermanTeam succeeded in winning the German Open 2007 and 2008 and has won the technical challenge and reached the quarter finals at RoboCup 2007. Therefore for RoboCup 2008 the team will be able to rely on the new architecture and the modules reimplemented in 2007. We will also integrate new developments which will focus on cooperative localization in order to cope with the modified and enlarged playing field and on cooperative team behavior in order to benefit as much as possible from the increased team size.

Some of the research described here is presented in more detail in two publications that were accepted for the RoboCup Symposium 2008 on acoustic localization [2] and constraint-based localization [3].

This paper focuses on changes in the implemented algorithms of the team's software system: First, the current vision system is presented briefly. Next, a new robot detection method using acoustic signals is presented, followed by a new particle based team ball model. Afterwards, an alternative localization approach is introduced. Finally, new aspects of our behavior control architecture focusing on team cooperation are described.

2 Vision System

Image processing is done in several steps. One part of the vision system relies on a color mapping which assigns color classes to pixels of the image. This mapping from colors in YUV-space to color classes is done using a manually created look-up table. The other part is based on intensity changes between neighboring pixels. At first the vision system creates segments along scan lines that are aligned vertically to the horizon. Color-based segments are adjacent pixels with the same color. Segments based on intensity changes are created when adjacent pixels have the same of these properties: *y-channel increases*, *y-channel decreases*, or *y-channel unchanged* based on a fixed threshold. These segments are the basis for all further image processing. Detection of the ball, the opponents and the goals is based on color. The detection of field lines is based on the intensity changes.

2.1 Opponent Player Detection

In order to avoid unwanted kicks into opponent or own players and for being able to dribble around them we developed a vision based players recognizer. For distance measurements we use bearing based measures to the lowest recognized red part of a robot. Unfortunately this methods does not work robust for blue robots, but is quite robust for red ones, see Fig. 1. Even though the distance measures provide some errors, the angle measure is more reliable, so the robots can recognize whether it is possible to dodge another robot by turning right or left easily.

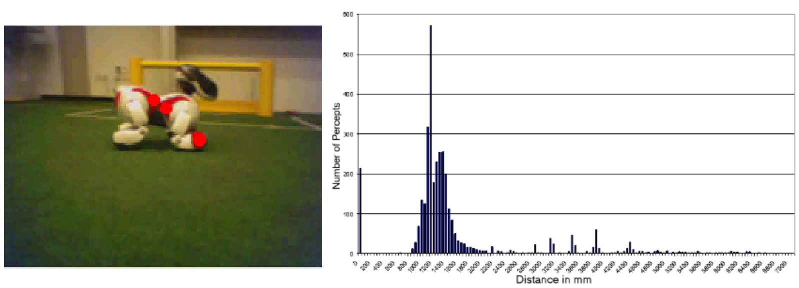


Fig. 1. Left: Players percepts, recognized by the red color of the robot. Right: the diagram shows the different recognized robot distance for a given scene.

3 Acoustic Robot Detection

In order to improve localization we are trying to explore possibilities of co-operative localization approaches in order to increase self-localization accuracy while also acquiring reliable information about teammate positions. As mentioned above, detecting teammates visually usually leads to inaccurate bearings and only rough distance estimates. Also visually identifying teammates is not possible.

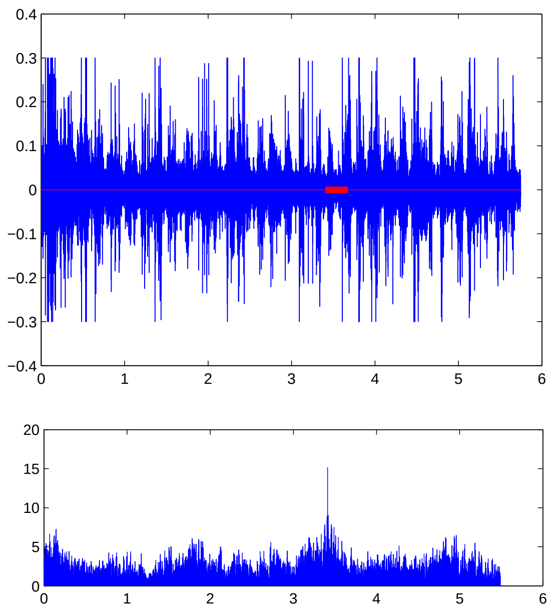


Fig. 2. An example for detecting a coded signal. Top: Noisy input signal. The red line indicates the amplitude of the actual coded signal. Bottom: Result of cross-correlation. The single peak shows the correct detection of the signal.

Therefore we are investigating different methods of gaining relative position information of a team of robots. Using the Aibo's stereo microphones and speaker it is possible to perform acoustic robot detection [2]. Determining the bearing of a known source of sound is possible using the phase offset of the detected signals of the two microphones. In order to achieve precise bearing measurements the exact phase offset is required. Due to interferences caused by reflected signals this can be very difficult. Provided that the clocks of the robots can be synchronized, it is also possible to measure distances by measuring the time a signal has traveled. Using cross-correlation of specific coded signals [4] it is possible to determine the exact time when a signal is received and also to identify the sender even under noisy conditions (cf. Fig. 2).

4 Particle Based Team Ball Model

With the increased number of players per team and the reduction of landmarks on the field the exchange of information about the environment becomes an increasingly important subject for research. After the introduction of a particle based ball model in the past [1], we now present a particle based team ball model. Following tests with various particle filter we successfully employed a model using multiple Kalman filters (used for the first time at the GermanOpen 2008). Each incoming ball particle from the team communication is treated as a potential measurement for a Kalman filter. First each particle is checked for valid coordinates and then either added as a measurement update to an appropriate, preexisting filter (center of the gaussian distribution of the communicated particle must be within one meter of the center of the Kalman position) or a new, additional Kalman filter is constructed with that particle as starting point [5]. At the beginning of each iteration all Kalman filters are time-updated and if any single Kalman filter is not updated by a measurement within 10 iterations it is erased. Through comparison of the variance of each filter an optimal team ball position can be chosen (cf. Fig. 3). Through this system we preserve all advantages of a Kalman filter and are still able to track several hypotheses, which is important to counter constant errors from particles of team members with an erroneous self localization.

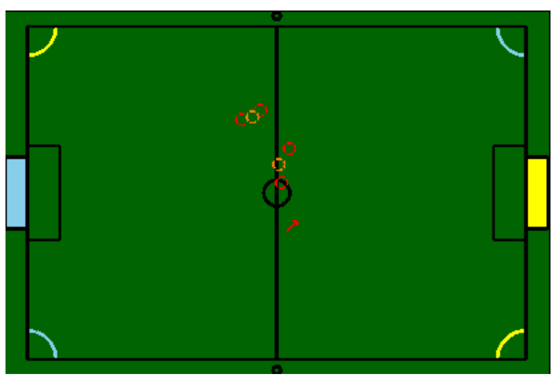


Fig. 3. This figure shows three communicated ball positions (red circles) and two calculated team ball positions (orange circles) for a player (red arrow)

5 Localization

The reduction of flags during the last years combined with an increasing field size made the use of field lines for localization purposes more and more necessary. In earlier years particle filters proved to be an adequate choice for self localization.

But it showed that the limited particle number can be problematic when using sensory data from field lines. For low particle numbers it is difficult to represent complex belief function. That is why we decided to try constraint based localization approaches, where the belief function is not being approximated by particles or Gaussians, but by constraint functions [3].

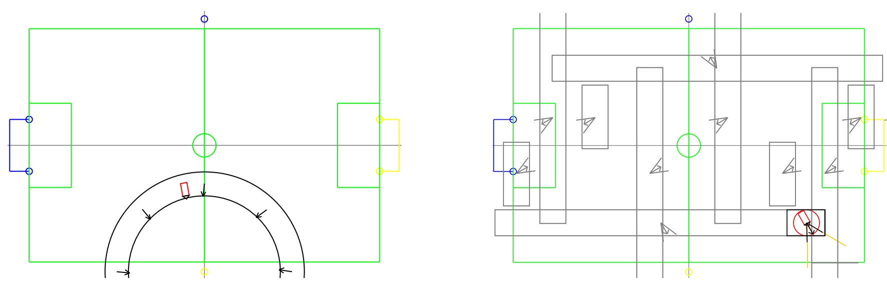


Fig. 4. Both figures show constraints, generated from percepts. Left: a circular constraint as generated from flag percepts. Right: a line constraint, generated from line percepts.

For self localization we consider percepts from flags, goals and from lines. The shape of the constraint is determined by the kind of sensor data and expected sensor noise, which is dependent from the percept distance. After having generated all constraints, we propagate the constraints with each other as long as there are no more constraints or the resulting solution space becomes empty. The position belief of the robot is stored in form of constraints as well and propagated with the sensory constraints as well. If, for some steps, the belief doesn't fit to the sensory constraints, or even if no new sensory data are available, the belief constraint boarders are increased at first. If sensory data remain inconsistent, we reset the belief to the sensor data constraints. The constraint propagation algorithm schematically:

Algorithm 1: Constraint Propagation with Minimal Conservative Intervals, MCI-algorithm

Input: constraint set $\mathcal{C} = \{C_1, ..., C_n\}$ with variables $\mathcal{V} = \{v_1, ..., v_k\}$ over domain U and a time bound T
Data: $D \leftarrow U$, $s \leftarrow 1$, $D_{old} \leftarrow \emptyset$
Result: minimal conservative k-dimensional interval D

```
while s < T & D ≠ D_old do
    D_old ← D;
    foreach C ∈ 𝒞 do
        foreach v ∈ 𝒱 do
            D(v) ← I_v(D ∩ C);
            //I_v is the min. conservative interval containing (D ∩ C)
        end
        D ← D(v_1) × ··· × D(v_n);
    end
    s ← s + 1;
end
```

6 Cooperative Behavior Control

In order to be able to quickly develop new behaviors for instance for playing soccer with four field players, it is necessary to have a good behavior architecture which supports multi-robot cooperation. Therefore, we are working on new features for the XABSL architecture based on hierarchical state machines which is applied by the GermanTeam since 2002 [6, 7]. The new features will further simplify creating cooperative behavior with XABSL [8]. It is possible to specify that a certain state of a state machine can only be executed by at most a given number of robots at the same time or that all robots are required to enter a certain state at the same time. Figure 5 demonstrates these new features.

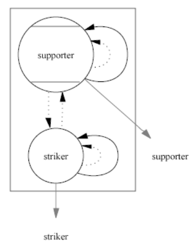
7 Conclusions

This team description paper mainly presents the new software modules of the GermanTeam 2008 based on the revised architecture. Other improvements are documented in other recent publications. A major goal of the new base system has been to make the development easier and more flexible. Vast parts of the modules were re-implemented to make the system leaner and faster [9–15]. An indication that this approach has been the right decision was the success at the RoboCup 2007 winning the technical challenge and reaching the quarter finals,

```
option play
{
  common decision
  {
    if (ball.distance <
        teammate.ball.distance)
      goto striker;
    else if (true)
      goto supporter;
  }

  initial state supporter
  {
    action
    {
      supporter();
    }
  }

  state striker capacity 1
  {
    action
    {
      striker();
    }
  }
}
```



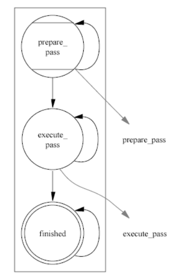
(a) State *striker* has capacity of one

```
option pass
{
  bool @receiver_or_sender;

  initial state prepare_pass
  {
    decision
    {
      if (action_done)
        goto execute_pass;
      else
        stay;
    }
    action
    {
      prepare_pass(receiver_or_sender = @receiver_or_sender);
    }
  }

  state execute_pass synchronized
  {
    decision
    {
      if (action_done)
        goto finished;
      else
        stay;
    }
    action
    {
      execute_pass(receiver_or_sender = @receiver_or_sender);
    }
  }

  target state finished
  {
    action
    {
    }
  }
}
```



(b) State *execute_pass* is executed synchronized

Fig. 5. Example a) shows a state machine for a simple role assignment, where the player closest to the ball assumes the striker role. This is realized by giving the state *striker* a capacity of one. Example b) shows an option for pass play. Only after both robots are finished preparing for the pass, e.g. aligning towards the other player, they will enter the state *execute_pass* synchronously.

only losing against the Northern Bites which later became the new world champion. Also the GermanTeam has won the rematch against the world champion in the final of the RoboCup German Open 2008.

References

1. T. Röfer, J. Brose, D. Göhring, M. Jüngel, T. Laue, and M. Risler, "GermanTeam 2007 - The German national RoboCup team," in *RoboCup 2007: Robot Soccer World Cup XI Preproceedings*, RoboCup Federation, 2007.
2. D. Becker, M. Risler, and O. von Stryk, "Mutual localization in a team of autonomous robots using acoustic robot detection," in *RoboCup 2008: Robot Soccer World Cup XII* (L. Iocchi, H. Matsubara, A. Weitzenfeld, and C. Zhou, eds.), Lecture Notes in Artificial Intelligence, Springer. to appear.
3. D. Goehring, H. Mellmann, and H.-D. Burkhard, "Constraint based belief modeling," in *RoboCup 2008: Robot Soccer World Cup XII* (L. Iocchi, H. Matsubara, A. Weitzenfeld, and C. Zhou, eds.), Lecture Notes in Artificial Intelligence, Springer. to appear.
4. T. Kasami, "Weight distribution formula for some class of cyclic codes," Tech. Rep. No. R-285, Univ. of Illinois, 1966.
5. M. Dietl, J. Gutmann, and B. Nebel, "Cooperative sensing in dynamic environments," (Maui, HI), 2001.
6. M. Lötzsch, M. Risler, and M. Jüngel, "XABSL - a pragmatic approach to behavior engineering," in *Proceedings of IEEE/RSJ International Conference of Intelligent Robots and Systems (IROS)*, (Beijing, China), pp. 5124–5129, October 9-15 2006.
7. M. Lötzsch, J. Bach, H.-D. Burkhard, and M. Jüngel, "Designing agent behavior with the extensible agent behavior specification language XABSL," in *RoboCup*

2003: Robot Soccer World Cup VII (D. Polani, B. Browning, A. Bonarini, and K. Yoshida, eds.), vol. 3020, Springer, 2004.

8. M. Risler and O. von Stryk, "Formal behavior specification of multi-robot systems using hierarchical state machines in XABSL," in *AAMAS08-Workshop on Formal Models and Methods for Multi-Robot Systems*, (Estoril, Portugal), May 12-16 2008.
9. T. Röfer, "Region-based segmentation with ambiguous color classes and 2-d motion compensation," in *RoboCup 2007: Robot Soccer World Cup XI* (U. Visser, F. Ribeiro, T. Ohashi, and F. Dellaert, eds.), Lecture Notes in Artificial Intelligence, Springer. to appear.
10. D. Göhring, "Cooperative object localization using line-based percept communication," in *RoboCup 2007: Robot Soccer World Cup XI* (U. Visser, F. Ribeiro, T. Ohashi, and F. Dellaert, eds.), Lecture Notes in Artificial Intelligence, Springer. to appear.
11. D. Göhring and H.-D. Burkhard, "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.
12. M. Jüngel and M. Risler, "Self-localization using odometry and horizontal bearings to landmarks," in *RoboCup 2007: Robot Soccer World Cup XI* (U. Visser, F. Ribeiro, T. Ohashi, and F. Dellaert, eds.), Lecture Notes in Artificial Intelligence, Springer. to appear.
13. M. Jüngel, H. Mellmann, and M. Spranger, "Improving vision-based distance measurements using reference objects," in *RoboCup 2007: Robot Soccer World Cup XI* (U. Visser, F. Ribeiro, T. Ohashi, and F. Dellaert, eds.), Lecture Notes in Artificial Intelligence, Springer. to appear.
14. M. Jüngel, "Bearing-only localization for mobile robots," in *Proceedings of the 2007 International Conference on Advanced Robotics (ICAR 2007), Jeju, Korea,*, August 2007.
15. M. Jüngel, "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. to appear.