CS Freiburg '99*

B. Nebel, J.-S. Gutmann, W. Hatzack

Universität Freiburg, Institut für Informatik
Am Flughafen 17, D-79110 Freiburg, Germany

1 Introduction

One of the interesting challenges in designing a successful robotic soccer team is the need to cover the entire loop from sensing over deliberation to acting. For example, successful ball passing needs good estimations of the position and velocity of the other players and the ball, projections into the future, planning ahead in order to create and exploit opportunities, and, finally, it requires to act accordingly.

One of our main goals in participating in RoboCup'99 was to enhance the design of our team *CS Freiburg* [5], which participated successfully in RoboCup'98 [1], in a way such that the robots can pass balls and are more flexible in their role assignment. For this purpose, we worked on enhancing the sensor data gathering and sensor data interpretation components, redesigned the deliberation components, and refined the behavior-based control module. The hardware design is basically the same. While we are aware of the fact that there are better alternatives for the basic platform and the kicker design, we decided to live with their limitations because they have proved to be reliable and robust enough for our purposes.

In RoboCup'99, our team lost the first game in its entire history, the semi-final against the Italian team. Nevertheless, we count the game as a success since this game was a pleasure to watch. In addition, we were able to demonstrate our ability to pass a ball (intentionally!). All in all, we came out as the 3rd in this competition. Counting our 1st place in RoboCup'98 (July 1998), the 1st place in the German open VISION RoboCup'98 (October 1998), and the 1st place in the German open VISION RoboCup'99 (October 1999), CS Freiburg is one of the most successful robotic soccer teams.

2 Team Development

Bernhard Nebel is head of the team, *Steffen Gutmann* is the main designer and coordinator of the development team, and *Wolfgang Hatzack* is responsible for the software development process, the global fusion component, and the user interface. In addition, the following graduate students (re-) designed and implemented components of the system. *Boris Bauer* and *Andreas Hill* (behavior redesign), *Markus Dietl* (global fusion, in

* This work has been partially supported by *Deutsche Forschungsgemeinschaft* (DFG) as part of the graduate school on *Human and Machine Intelligence*, by *Medien- und Filmgesellschaft Baden-Württemberg mbH* (MFG), and by *SICK AG*, who donated a set of new generation laser range finders.

particular ball position estimation), *Burkhard Dümmler* (integration of new laser scanners), *Immanuel Herrmann* (all mechanical components, in particular kicker design), *Kornel Marko* (simulator), *Christian Reetz* (tactical decision making and behaviors), *Augustinus Topor* (path planning), and *Maximilian Thiel* (vision and low-level interfaces to the Cognachrome board).

3 Robots

The robot hardware we use is described in detail [5]. As in last year's competition, we used Pioneer 1 robots enhanced by custom-built kickers, SICK laser scanners, and the Cognachrome vision system. For local information processing we used Librettos 110CT. For communication between the robots and the off-field computer, the WaveLan radio ethernet was employed.

4 Perception

The main sensors we use are *laser range finders* (now the new *LMS 200* range finders, which have an accuracy of 1cm) and the commercially available *Cognachrome* vision system [5]. In the '98 team design we used only 5 laser scans and 8 frames per second, although the devices could give us 35 laser scans and up to 60 frames per second. Furthermore, we only had very inaccurate time stamps for the measurements. In order to raise the data rate to the maximal possible rate, we modified the Cognachrome software and implemented new modules for gathering the data. Additionally, we started to use a real-time extension of Linux — *RTLinux* [2] — in order to cope with the high data rate from the laser range finder (500 KBaud) and to assign millisecond accurate time stamps to all measurements. Using the higher data rate, we got much better estimates for the velocity of moving objects on the field.

While self-localization based on the laser range finders give us very accurate and robust estimations of our own positions [6], the estimations of the ball is not very accurate. In the vision module, we now use the shape of the ball to exclude false positives and to increase the accuracy of the estimation of the ball position. Additionally, in order to compensate for the lack of stereo vision, we use the entire group of robots to estimate the ball position more reliably and precisely than any single robot with monocular vision can do using ideas from [4].

5 World Model

The world model is similar to the one we developed for RoboCup'98 [5]. Each robot builds a local world model about its own position on the field, the ball position, and the position of other players. This model is extended by the results of the global fusion component that runs on the off-field computer and combines all estimates from all other players. While this component gives much more accurate estimations, in particular of the ball position, and enables us to distinguish friends and foes, it is always a bit outdated (100–200 msec).

6 Communication

Our robots communicate – using the WaveLan radio ethernet – in order to build up the global world model, to negotiate about which robot is going to the ball, and to initiate ball passing.

7 Skills

The basic ball handling skills are, from our experience, very important. However, it is very difficult to implement them in a robust way. For example, when arriving in Stockholm we noticed that our behaviors had to be tuned to the carpet which was significantly different from the one we used on our exercise field in Freiburg. While one robot can handle a ball usually adequately, we were not able to implement a reliable *ball intercepting* behavior because the responsiveness of the Pioneer is not adequate.

8 Strategy and Tactics

One of the main differences to our '98 team is that we use now a more principled way for choosing actions. We use an approach based on behavior networks as developed by Maes [7] and refined for the purpose of playing (simulated) robotic soccer by Dorer [3]. This approach enabled us to express our tactics in much more modular and extensible way so that we were able to modify our tactics in a significant way even during the competition in Stockholm. Furthermore, we extended our cooperative play approach. First of all, we do not have fixed areas of competence anymore, but roles that can be filled (and reassigned), such as defender, mid-fielder, and forward. In connection with that, the players negotiate which robot is going to the ball. Secondly, we have true cooperative play when the ball has to be passed. The player possessing the ball calls for a team mate to go to a good position and plays the ball when the team mate signals that it has reached this position. Another significant difference to the '98 team is our new path planning component. Now we use a potential field approach that tries to stay away from obstacles, while in 1998 we used a geometric path planner that tried to compute the shortest path.

9 Special Team Features

Our special feature used to be that we use laser range finders in order to do self-localization and object recognition [5,6]. This year, the teams from Stuttgart and Tübingen used laser range finders as well. As it turned out, laser range finders alone do not guarantee success.

Furthermore, other teams, such as the Italian and the Munich team demonstrated that reliable and accurate self-localization can be done solely based on vision. Although we demonstrated that our team is still competitive, the other teams proved to be very good (either at RoboCup'99 or the German open VISION RoboCup'99). In particular, we noticed that the factor of speed (who is first at the ball?) seems to become a crucial issue once the sensor interpretation and world modeling problem appears to be "solved."

10 Conclusion

Although we were satisfied (well, ...) with our performance at RoboCup'99, there are, of course, a number of points where our team can be improved. Some of these points are on an abstract level such as model-based object recognition, cooperative path planning, situation adapted placement of players, adaptable tactics, more adaptive vision, and so on. Other points are on the hardware level such as improving the responsiveness and speed of our players and improving the robustness of the vision (using other cameras and vision hardware), building better kickers, etc. Which of these points we are able address until the next competition is not clear. However, we intend to participate in the next RoboCup and hope to increase th level of play again.

References

1. M. Asada and H. Kitano, editors. *RoboCup-98: Robot Soccer World Cup II.* Springer-Verlag, Berlin, Heidelberg, New York, 1999.
2. M. Barabanov and V. Yodaiken. Introducing real-time Linux. *Linux Journal*, 34, 1997.
3. K. Dorer. Behavior networks for continuous domains using situation-dependent motivations. In *Proceedings of the 16th International Joint Conference on Artificial Intelligence (IJCAI-99)*, Stockholm, Sweden, Aug. 1999. Morgan Kaufmann.
4. J.-S. Gutmann, W. Burgard, D. Fox, and K. Konolige. An experimental comparison of localization methods. In *Proceedings of the International Conference on Intelligent Robots and Systems (IROS'98).* IEEE/RSJ, 1998.
5. J.-S. Gutmann, W. Hatzack, I. Herrmann, B. Nebel, F. Rittinger, A. Topor, T. Weigel, and B. Welsch. The CS Freiburg robotic soccer team: Reliable self-localization, multirobot sensor integration, and basic soccer skills. In Asada and Kitano [1].
6. J.-S. Gutmann, T. Weigel, and B. Nebel. Fast, accurate, and robust self-localization in polygonal environments. In *Proceedings of the International Conference on Intelligent Robots and Systems (IROS'99).* IEEE/RSJ, 1999.
7. P. Maes. Situated agents can have goals. In P. Maes, editor, *Designing Autonomous Agents: Theory and Practice from Biology to Engineering and Back*, pages 49–70. MIT Press, Cambridge, MA, 1990.