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1 Introduction

The development of our robotic soccer team over the last three years has resulted in a very strong team. One of the reasons is most probably the sensor interpretation component, which leads to quite accurate and robust estimations of the world state [4,11,7]. Knowing where everything is makes playing soccer much easier than when one has only a vague idea where the ball might be, or when one only has a rough estimation of one's own position and orientation on the field.

Although we are quite satisfied with the performance of our sensor interpretation in general, it happens nevertheless that the ball position is misjudged or player positions are wrongly estimated. Using cooperation in the sensing process (by fusing all sensor data globally) can help to alleviate many of these problematical situations – which is one topic we intend to work on.

Another important topic where we still see room for improvement is the action selection process. We intend to work on the specification and execution of complex behaviors, using an approach that is based on Dorer's [2] extended behavior networks, which can be viewed as a particular form of decision-theoretic planning. Based on this approach, we hope to be able to model more of the possible game situations than we had modeled before.

2 Team Development

Bernhard Nebel is head of the team and *Thilo Weigel* is coordinating the (software) development process. *Markus Dietl* works on refining local and global world modeling, *Burkhard Dümmler* integrates the new goalkeeper into the team, *Klaus Müller* redesigns the action choice mechanism and *Maximilian Thiel* is responsible for the ball recognition, in particular the one for the new goalkeeper. *Steffen Gutmann* addresses miscellaneous issues in order to improve the team's overall performance.

3 Robots

The robot hardware we employ is very similar to the one we used in the previous two years [4,7]. Our field players are Pioneer 1 robots enhanced by laser scanners and vision

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systems. This year, we use a new kicking mechanism, which has been designed and built by SICK. For local information processing we use again *Toshiba 110CT Librettos* together with the *WaveLan radio ethernet* for communication between the robots and the off-field computer.

The goalie was completely redesigned. Now we use a Pioneer DX-2 robot. The expectation is that this robot is much more responsive than the Pioneer 1 and is able to track the ball much better using the pan-tilt Sony camera.

4 Perception

As in last year's competition each player is equipped with a *SICK LMS 200 laser range finder* for self-localization and player recognition [7]. The field players perceive the ball with the commercially available *Cognachrome vision system*, whereas the goalkeeper uses the *Sony EVI-D30 camera* in conjunction with the *Imagenation PXC 200 frame grabber*. We will refine our vision module for the field players to further decrease the number of cases where field lines or objects different from the ball lead to false positives [9]. For the goal keeper we expect a more reliable ball recognition than for the field players since we count on a better vision hardware and can apply our own color training mechanism here.

5 World Model

The world model is similar to the one used for RoboCup'98 and RoboCup'99 [4,7]. 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. This year we incorporate a model-based player recognition approach in order to improve the accuracy of the position estimates for other players, in particular the opponent goalie. Further, we apply sophisticated probabilistic methods in order to maintain a coherent world model. For instance, the global ball position is estimated using a combination of Markov localization and Kalman filtering [1].

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

Our experience from the last competitions led us to the conclusion that more specialized and less complex basic behaviors are the key to a highly responsive and smooth overall player behavior. Through a complete redesign of the skills as of last year's competition

[4], we expect the field players to react in a more adequate way to a wider range of game situations. By adding new skills like a fast ball interception behavior and an elaborate ball kicking behavior which plays the ball to free space close to the opponents goal, we hope to improve considerably the current team performance.

Exploiting the possibility to turn the cameras head instead of turning the entire robot in order to search or track the ball, we partially redesigned the behavior of the goalkeeper. This way the goalkeeper hopefully will not run into situations in which he accidentally might push the ball into our own goal.

8 Strategy and Tactics

The action selection mechanism we use is an approach based on behavior networks as developed by Maes [6] and refined for the purpose of playing (simulated) robotic soccer by Dorer [2]. While we used a similar approach already last year [8], this time we expect to have a more fine-grained modeling that is very similar to decision-theoretic planning.

As in 1999, field player roles are assigned dynamically taking into account the current game situation [7]. Cooperative play is enabled through the possibility for players to negotiate about their future actions. Direct ball passing and sending a team mate to a location whereto a player is about to kick the ball will hopefully result in successful and aesthetic robotic soccer.

In the semi-final game against the Italian team last year, our robots were removed from the field one after the other because they supposedly violated the 10-seconds-rule while trying to get the ball, which was stuck in the goal area. This year, the action selection module will consider such special game situations and take them into account in the deliberation process. Another special game situation where improvements are possible is the ball replacement by the referee after a game stuck. If the robots can detect such a game situations, they will be able to find the replaced ball much faster – hopefully faster than our opponents. Interestingly, it seems quite straightforward to integrate these features using the formalism of the new action selection approach.

9 Conclusion

We are basically satisfied with the design of our team, and believe that we cannot improve much on, e.g., the interpretation of laser scans [5,3] and the reactive path planner [10].[1] There are nevertheless a few issues we believe are worthwhile to work on, both from a scientific and a performance point of view. One is the area of *cooperative sensing*, where we hope to make the sensor interpretation process more robust using a global fusion of all sensor data. Another area is the modeling of the game and the corresponding *action selection mechanism*. Using a very declarative approach will enable us to model more game situations. Hopefully, this will then result in a more effective game.

[1] Well, some improvements are always possible. In particular the path planner may be improved by anticipating the movements of other players. While this is an interesting research topic (multi-robot path-planning), the common believe in our group is that we cannot improve the performance of our play much by incorporating a cooperative path-planning component.

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