Evaluation of the Performance of CS Freiburg 1999 and CS Freiburg 2000*

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Abstract. One of the questions one may ask when following research in robotic soccer is whether there is a measurable progress over the years in the robotic leagues. While everybody who has followed the games from 1997 to 2000 would agree that the robotic soccer players in the F2000 league have improved their playing skills, there is no hard evidence to justify this opinion. We tried to identify a number of criteria that measure the ability to play robotic soccer and analyzed all the games CS Freiburg played at RoboCup 1999 and 2000. As it turns out, for almost all criteria, there is a statistically significant increase for CS Freiburg *and* the opponent teams demonstrating that the level of play has indeed increased from 1999 to 2000.

1 Introduction

In robot soccer as in human soccer, the abilities to be developed or improved do not correlate with the overall criterion of success, i.e. goals, in a direct manner. With respect to a representative analysis of the relative performance of two teams playing against each other, the distribution of goals in a single game is subject to too many contingencies and therefore no adequate basis for an evaluation of *team strength*. Even if we consider many games, it is very often impossible to arrive at statistically significant results. For instance, when comparing the average goal rate of RoboCup 1997 with the average goal rate of RoboCup 2000, one notices that this rate has increased from 0.05 goals/minute to 0.1 goals/minute. However, the increase is not significant on the 95% level. Furthermore, for the *CS Freiburg* team the goal rate is approximately the same for 1998–2000, namely, around 0.2 goals/minute [4], and there is no statistically significant difference.

More differentiated data is required in order to assess the progress made by a team on the basis of a statistical analysis. In the case of RoboCup, the task of obtaining relevant data is simplified by a relatively restricted repertoire of possible actions. Asada et al. [1] distinguished three major areas of the RoboCup *physical agent challenge*: *ball moving*, *ball catching* and *cooperative behavior*. Of these, cooperative behavior is currently almost negligible due to the relatively small size of the field and the lack of hardware suitable for receiving the ball. For this reason, we see only very few passes during the games. Similarly, the robots cannot catch the ball. The main focus of this

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paper will therefore be on the area of *ball moving*, supplemented by *ball possession* and *shooting*.

In order to assess the improvement over the years, we tried to identify a number of different criteria in this skill area and evaluated our team and the opponents for RoboCup 1999 and 2000 according to these criteria. As it turns out, CS Freiburg and our opponent teams showed in most cases a statistically significant improvement, justifying the impression one gets when watching the two sets of games: There is a measurable increase of skills from 1999 to 2000.

2 Approach

The material available for survey consists of video and Web-Player recordings of the matches of CS Freiburg. The restrictions imposed by the manual evaluation of visual recordings make an approach similar to that of Tanaka-Ishii et al. [3] impossible. Based on the "giant set of log data" of the simulator league, they considered "low-level events" to compute values such as *compactness* or *x/y-correlation*, which, in addition, seem less meaningful with respect to the F2000 league's limited complexity (number of players, size of field, etc.). When based on video recordings, human judgment of robot behavior depends on the ascription of intentionality to their actions regardless of their internal state. The lack of cooperative behavior as well as the unclear application of the charging rule suggest concentration on the ball as a focus of such ascriptions.

The following survey thus relies on a distinction of different kinds of ball possession as a global measure of behavior. Ball possession is particularly relevant for the physical agent challenge in contrast to the simulator league because physical components (movement) and vision and sensor fusion (localization) are an integral part of this challenge [2]. The different categories of ball possession are constituted by relating them to the existing repertoire of actions of the CS Freiburg team [4] and assuming that the best possible action which may conform to the observed behavior is executed. In the following, we will distinguish between different kinds of (non-) ball possession:

- **ball free**: no player is at the ball.
- **both at ball**: at least one player of each team is at the ball. The ball is stuck between the players or moves little. It is usually followed by a *ball free* situation.
- **ball possession**: only one team is in possession of the ball, which may be differentiated according to the following criteria:
  - **ball stuck**: at least one player of one team is at the ball. The ball is stuck between two players of the same team or between a player and the wall. Since this is obviously an undesirable state, one can assume that the player(s) is/are prevented from executing an action by the interference of another player or the wall.
  - **active**: a player of one team is at the ball and is executing one of the following actions in a goal-directed manner: *TurnBall*, *DribbleBall*, *BumpShoot*, *ShootGoal*, *MoveShootFeint*, *ShootToPos*, and *TurnAwayBall*.
  - **other**: as *active*, but not goal-directed. This comprises ball possession without visible activity as well as dribbles or shots on the own goal.

Dribbles beginning with a free direct path to the opponent's goal (disregarding the goalkeeper) are distinguished from dribbles beginning with an obstacle, i.e. an opposing player, between the ball and the goal. This distinction allows an evaluation of the defensive positioning of the players of a team, insofar as a team with more mobile players and a better line-up will allow a lower share of dribbles without obstacle. A dribble without obstacle ends with a loss of ball (*ball lost*), with a shot (*with shot*), or with the interference by another player. In the latter case, its description will be continued as a dribble with obstacle. A dribble with obstacle ends with *ball lost*, *with shot*, or the blocking of the ball or player by an opposing player (*blocked*). A player dribbling with the ball in the direction of the opponent's goal and thereby entering the penalty area is assumed to finish this dribble with a shot to the goal, regardless of whether the player does so.

3 Evaluation

Data was gathered from eight hours of video recordings. Situations in a game which were not or only partly recorded were recovered from Web-Player recordings. The net playing time amounts to 247 minutes, of which 104 minutes or approx. 13 minutes per game fall to the eight matches of CS Freiburg in RoboCup 1999 (five in the qualifying round, three in the finals) and 143 minutes or approx. 14.3 minutes per game fall to the ten matches of CS Freiburg in RoboCup 2000 (seven in the qualifying round, three in the finals).

3.1 RoboCup 1999 vs. RoboCup 2000

In order to get an idea of the development of the game as a whole, the average values of a category for 1999 are compared with those for 2000. Because a comparison of team-specific categories does not yield significant results, only data from categories registered for both teams together is taken into account. The development of the game will thus characterized by the categories *ball free* and *both at ball* (see Figure 1).

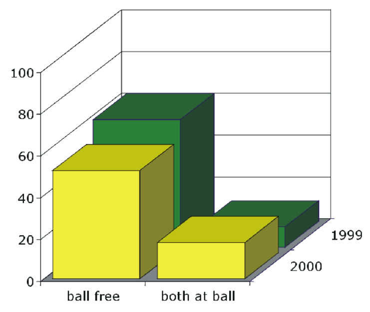

Fig. 1. Ball possession in RoboCup 1999 and 2000

As can be seen from the graph in Figure 1, the amount of time with a *free ball* has decreased. At the same time, the share of *both at ball* situations of the net playing time increased from approx. 10% in 1999 to approx. 18% in 2000.[1] Both changes are probably due to improvements in vision and effectors (e.g. omni-directional movement).

3.2 CS Freiburg 1999 vs. CS Freiburg 2000

When comparing the amount of ball possession of CS Freiburg between 1999 and 2000, one notices that the amount of time for ball possession in general and for *active possession* in particular is almost the same for 1999 and 2000 (see Figure 2). Interestingly,

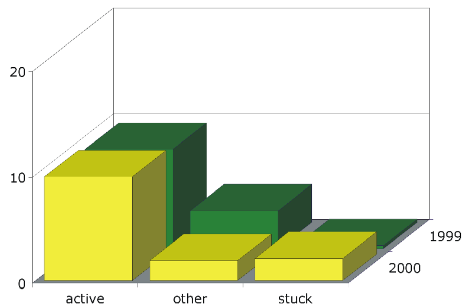

Fig. 2. Ball possession of CS Freiburg in RoboCup 1999 and 2000

however, the CS Freiburg team was able to reduce the amount of time of *other ball possession*, i.e., moving into the wrong direction. In addition, the number of *ball stuck* situations has increased. However, in general, there is no statistically significant change in the area of ball possession.

Because of the new kicking device, a number of statistically significant improvements were visible. For instance, we recorded 14.3 shots per game on average in 2000 instead of 9.8 shots in 1999, and this is statistically significant. Also the average length of a shot increased statistically significant. However, for dribblings only some tendencies were visible, which are not statistically significant (see Figure 3).

The number of situations losing the ball during dribbling without an obstacle in the way has decreased, showing a better ball steering behavior. Furthermore, we could finish a dribbling with an obstacle in its way more often with a shot. However, these two changes were not statistically significant.

There was a statistically significant increase in dribblings with an obstacle in its way. This change, however, does not demonstrate an increase of the skills of CS Freiburg, but a visible better placement of the opponents.

[1] Both of these changes are statistically significant at the 95% level.

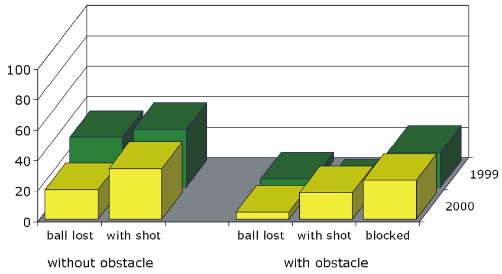

Fig. 3. Dribblings of CS Freiburg in RoboCup 1999 and 2000

3.3 CS Freiburg and Opponents in RoboCup 1999 vs. CS Freiburg and Opponents in RoboCup 2000

Finally, we will have a look at how much the difference between CS Freiburg and its opponents changed from 1999 to 2000. As mentioned above, we had 14.3 and 9.8 shots in each game on average in 2000 and 1999, respectively. The other way around, our opponents shot 7.2 and 4.6 times on average per game in 2000 and 1999, respectively. While the difference between CS Freiburg and its opponents is statistically significant at the 90% level in both cases, we see a tendency that the opponents are coming closer. A similar statement can be made for shots at the opponents goal. Again we have in both years a statistically significant difference and the opponents come closer.

Reconsidering the ball possession criterion, we get a graph as in Figure 4. In all

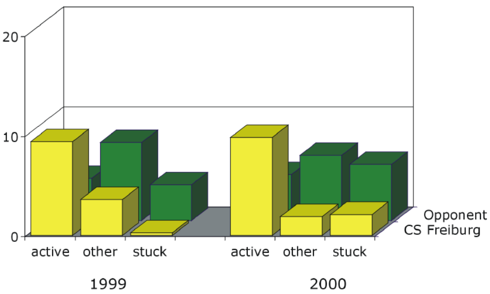

Fig. 4. Ball possession of CS Freiburg and its opponents in RoboCup 1999 and 2000

cases, we have a statistically significant difference between CS Freiburg and its opponents. The most interesting observation is that the *ball stuck* situations increase for both sides and that the *other* situations decrease.

Finally, when looking at the dribbling capabilites (Figure 5), one notices that from

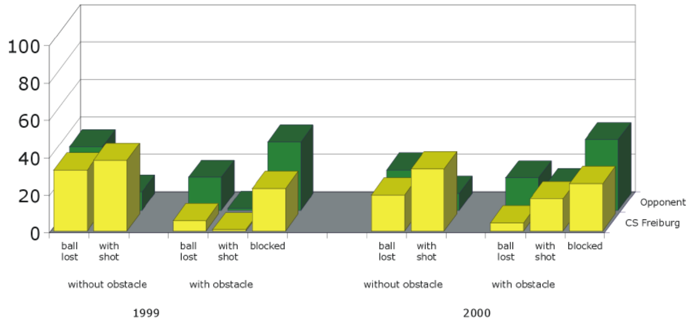

Fig. 5. Dribblings of CS Freiburg and its opponents in RoboCup 1999 and 2000

1999 to 2000 CS Freiburg has not lost its leading edge, e.g., in finishing a dribble with a shot. It is interesting to note, however, that CS Freiburg as well as the opponents much more often finished a dribble with a shot in general.

4 Conclusion

We tried to identify criteria which can be used to measure the progress of robotic soccer teams in order to assess the progress of our own team as well as of the other teams. As it turns out, for most criteria such as ball possession, dribblings and number of shots a statistically significant increase could be identified for CS Freiburg and the opponents. This confirms the impression that the level of play has improved from 1999 to 2000.

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