Robot Soccer KheperaSot League: Challenges and Future Directions

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Summary. Robot soccer fosters AI and intelligent robotics research by providing a standard problem where a wide range of technologies can be integrated and examined. In order for a robot team to actually perform in a soccer game, various technologies must be incorporated including: design principles of autonomous agents, multi-agent collaboration, strategy acquisition, real-time reasoning, robotics, and sensor-fusion. In this paper, we discuss the specific features of the KheperaSot league, describe the winner of the last two World Cups, and discuss the future directions of the KheperaSot league.

1 An Overview of Robot Soccer

Robot soccer pits teams of fast-moving robots under a dynamic environment [9]. Robot soccer fosters AI and intelligent robotics research by providing a standard problem where a wide range of technologies can be integrated and examined [1].

Today two international robot soccer federations, RoboCup [7, 5] and FIRA [2], organize competitions in an eclectic range of categories. Those competitions are accompanied with technical conferences. The first international robot soccer tournament MiroSot'96 was held at KAIST, Korea, in November, 1996. At the time of writing, we can count more than ten different robot soccer leagues from RoboCup and FIRA [6, 3]. A taxonomy of the robot soccer leagues could start with the vision system used. The *global vision* group contains all the leagues that allow a global vision system (camera that gives an eye-bird view of the playing field). The image processing is done on a PC that controls the robots via a radio link. Whereas the *local vision* group contains all the leagues that require that vision processing be done on the robots themselves. In this second group, the robots achieve a higher level of autonomy. Only wheeled robots are used in the global vision group. Whereas, the local vision group can be subdivided into wheeled robots and legged robots. Simulation leagues provide a test bed for multi-agent research for those who do not have access to real robots.

Section 2 provides an overview of KheperaSot league. Section 3 describes the winner of the last two KheperaSot world cups. Section 4 discusses the future of the KheperaSot league.

2 KheperaSot League

The KheperaSot league has its origin in the 1987 Danish Robot Soccer Championship organised by Henrik Hautop Lund.

Environment The Khepera robot (see Figure 1) is a two-wheeled robot equiped with a ring of 8 IR proximity sensors, wheel encoders and a linear camera turret (Figure 2) that produces a horizontal linear image of 64 pixels with 256 grey-level. These 64 pixels allow the detection of the ball (a yellow tennis ball), the goal (large black zone), and the opponent robot (wearing a black and white stripped shirt). The main difficulties of the KheperaSot league reside in the limited computational resources (512K of memory) and the low resolution of the linear camera.

Fig. 1. Khepera robot

Fig. 2. Linear camera turret

The KheperaSot playing field is 105 centimetres long and 68 centimetres wide (see Figure 3). A match consist of five rounds of at most four minutes each. A round ends when a goal is scored or when the ball does not move for thirty seconds. The team that scores the largest number of goals is declared the winner. At the beginning of a round the ball is to be placed at the centre of the field. The players are positioned differently at the start of each round. The referee point out 180-degree rotation symmetric starting positions. Each player starts facing its opponent's goal line. A starting position in the opponent's half is possible. The KheperaSot environment is shown in Figure 4.

Specific challenges Unlike leagues allowing a global vision system, the KheperaSot robot has to find it own position in a completely symmetric environment. The only information that the robot can exploit is that it is facing

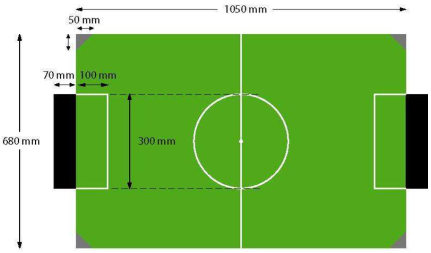

Fig. 3. KheperaSot's floor plan

Fig. 4. KheperaSot's arena

the opponent's goal line at the start of each round. But if the robot get disoriented in the course of a round, it is impossible to determine which goal is the opponent goal from visual clues. Apart from intrinsic limitations, pushing by the opponent can create odometry errors. It was not uncommon in the first years of the competition to see confused robots score own goals. The cylinder shape of the robot and the grooves on the tennis ball makes dribbling the ball a challenging task. During a game, the ball might be pushed into a corner. It is not a trivial task to unstuck the ball from the corner.

Advantages Robot soccer leagues which require many robots and a large field such as RoboCup - F180, have budget of at least 30,000 US dollars for the hardware [8]. KheperaSot requires a much smaller budget. Moreover the playing field can fit on a desktop. A single person can look after a KheperaSot system, whereas the other leagues have typically teams of half-a-dozen people.

3 Description of Kheperoo

Kheperoo, QUT's entry in the KheperaSot league, has narrowly won the last two KheperaSot World Cups. In this section, we give an overview of the system and describe the strategy used.

Kheperoo has adopted the motto "Attack is the best defence". Its software architecture is a finite state machine with multiple threads running concurrently. Kheperoo's top priority in the game is to get to the ball first and move the ball away from the opponent. If Kheperoo manages to move ball away from the opponents vision field, the opponent will need some precious time to recover the ball. During that time, our robot can take advantage of the opponent confusion and push the ball towards the opponent line. Kheperoo deliberately does not try to head for the goal directly, but simply the opponent line. The rationale behind this decision is that the opponent is more likely to be in between its goal and the ball because of the symmetry of the starting condition. After racing to the ball, Kheperoo dribbles the ball towards the opponents goal line based on the estimatated orientation provided by the wheel-encoders (they play the role of a virtual compass for a short period of time). If Kheperoo is lucky, the ball may end up directly in the opponents goal. Most of the time, the ball will get stuck against the opponents wall. This situation triggers a complex behavior to push the ball into the opponent goal. An overview of Kheperoo finite state machine is shown in Figure 5.

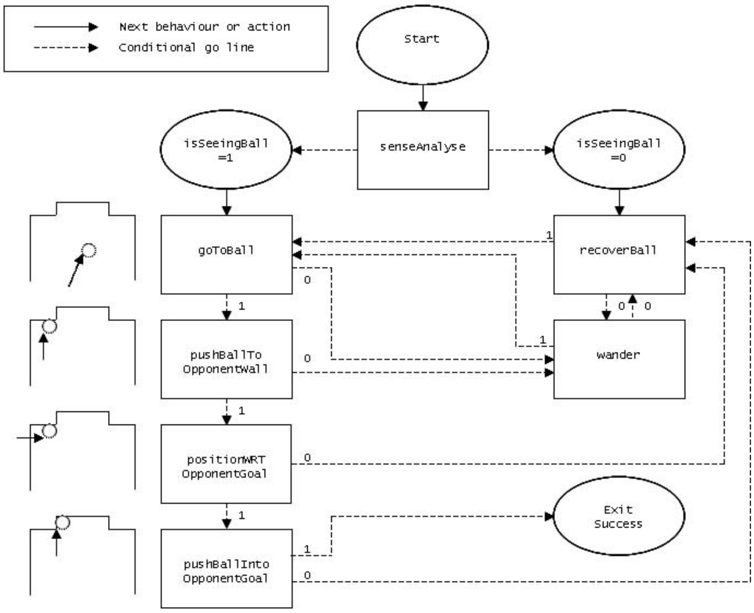

Fig. 5. Overview of Kheperoo's finite state machine

Some tricks Apart from the main control thread, a watchdog thread is used to monitor the robot's wheels' status. The robot has to be able to detect and stop when it run against a wall to avoid the wheel slippage problem and prevent any damage to the robot itself. The actual wheel speeds and desired wheel speeds are compared to determine whether a static obtacle is in the way. Kheperoo resets its estimated pose whenever it moves parallely to a side wall or whenever it stops in front of the opponent wall (after attempting to circle the ball). Complex behaviors such as *unstuck the ball from the corner* also use the watchdog to complete their tasks. To unstuck the ball, first, the robot will position itself carefully with respect to the ball, then push the ball straight to the wall until some resistance is felt. After that, the robot will spin on itself to unstuck the ball. Hopefully, the ball will roll out from the corner.

For dribbling the ball, we use the fact that it is more effective to control the ball direction when the ball is rolling because the ball already has a moving momentum. One method to make the ball roll straight away before the robot starts to dribble is to give a strong kick to the ball. After the kick, the ball usually rolls in a straight line and the robot can continue to forward dribble the ball. In some case, the ball does not roll in a straight direction and the robot needs to circle around the ball to recover its dribbling direction. But at least after the kick, the ball has moved closer to the opponent side.

4 Future Directions

As discussed above the KheperaSot in its current form poses challenges in motion control, navigation and self-localisation, as well as in higher level autonomous behaviour design and implementation.

The reason why we support and encourage the KheperaSot league is the complete autonomy of the robot combined with its small size. The autonomy enhances the educational value of the tournament by putting it *at par* with prospective autonomous mobile robot applications that have to rely entirely on their own sensors to acquire information of the world around them. The autonomous nature of the KheperaSot league also provides a natural evolutionary pathway for the game, allowing it to maintain challenges as the technology and the experience of the players advance. The size limitation lowers the entry barrier for participants in relation to other robot soccer tournaments, making it more accessible to individuals and small teams with modest funding and infrastructure support. The size limitation also poses challenge for hardware technology. It pushes the limits of how much processing and sensing can be put into the small package at a reasonable cost. However the size is not so small as to requiring miniaturisation technology beyond the reach of standard electronics and construction techniques.

The most obvious extension of the current KheperaSot is the replacement of the current 1D vision by a 2D colour camera. Two solutions are already available: the Khepera adaptation of the CMUcam by k-team (`www.k-team.com`) and 2D camera developed by the Paderborn team [4]. Both allow vision image processing on the robot. Upgrading the vision system will provide for enriched realism of the game without a large increase in cost. With a 2D vision system the KheperaSot league will have all the features of the humanoid and AIBO leagues, which are all autonomous, except the complications of legged locomotion. For some time to come, wheeled locomotion will allow a much faster games than the legged leagues resulting in more interesting games. Most importantly, 2D vision will facilitate multi-player teams and thereby largely expanding the opportunities for collaborative strategies. An expansion to 3 player teams seems feasible with a moderate enlargement of the playing field and without fully loosing the *desktop* characteristic of the KheperaSot league. One may argue that increasing the number of players per team also rises the cost. However, because of the autonomy of the robot, teams could be formed by students of different institutions each providing their own robots. Our ultimate vision would be to bring the cost to a level where individual enthusiast could buy their own pocket sized soccer robot for participating in a school or neighbourhood team. Up to now the league uses Khepera robots, hence its name, however the rules do not exclude other manufacturers. As more powerful small size and low power SBC (single board computer) boards come on the market at low prices, such a the Gumstix boards (`www.gumstix.com`). We expect alternative robots to be built for the game.

References

1. Minoru Asada and Hiroaki Kitano. The robocup challenge. *Robotics and Autonomous Systems*, 29(1):3–12, 1999.
2. Federation of International Robosoccer Association. About fira. `http://www.fira.net/about/overview.html`.
3. Federation of International Robosoccer Association. Fira federation of international robot-soccer association. `http://www.fira.net/index.html`.
4. Teerapat Chinapirom, Tim Kaulmann, Ulf Witkowski, and Ulrich Rückert. Visual object recognition by 2d-color camera and on-board information processing for minirobots. In *Proceedings of the FIRA Robot World Congress*, Busan, South Korea, 26 - 29 October 2004.
5. The RoboCup Federation. Robocup. `http://www.robocup.org/games/31.html`.
6. The RoboCup Federation. Robocup official site. `http://www.robocup.org/02.html`.
7. The RoboCup Federation. Robocup : Brief of history. `http://www.robocup.org/overview/23.html`, 1998.
8. A. Peel. The roobots: Robocup used for research and teaching. *Autonomous Minirobots for Research and Edutainment (AMiRE)*, pages 173–182, 2003. 807.
9. H.L. Sng, G. Sen Gupta, and C.H. Messom. Strategy for collaboration in robot soccer. In *Electronic Design, Test and Applications, 2002. Proceedings. The First IEEE International Workshop on*, pages 347–351, 2002.