STRATEGIC CONTROL OF MOBILE ROBOTS

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Abstract: We have developed a method of representing robotic soccer game. This representation is used for controlling robots playing soccer. Our approach to robot soccer is to view it as a local interaction game, which reduces the need for centralized control. In this paper we describe both hardware and software implementation that is used by robots. Virtual grid is described. The virtual grid is much more efficient than representation of game using natural coordinates of robots. This representation can be efficiently used for a description of game strategies, which can be directly used for a faster control of robots. We also show how a can be learned and illustrate our approach using the latent semantic analysis. Strategy learning is important both for developing successful players and also for discovering strategies of the opponent team.

Keywords: Robots, Game theory, Image analysis, Autonomous mobile robots, Robot navigation.

1. INTRODUCTION

The typical example of distributed control system with embedded subsystems is the task of controlling physical robots playing soccer (Kim, J., Kim, D., Kim, Y.; Seow, K., 2004). The selection of this game as a laboratory task was motivated by the fact that the realization of this complicated multidisciplinary task is very hard. The task can be divided into a number of partial tasks (evaluation of visual information, image processing, hardware and software implementation of distributed control system, wireless data transmission, information processing, game strategy, and controlling of robots). The task is attractive both for students and teachers, and allows direct evaluation and comparison of various approaches. For the improvement of the game strategy, we develop an abstract description of the game and propose how to use this description for e.g. learning of rules. We also take inspiration from the ant-like systems that reduce the need of complexity of individual robots and lead to robust, scalable systems (Deneubourg, J.L., Goss, S., Franks, N., Sendova-Franks, A., Detrain, C., Cretien, L., 1991, Holland, O., Melhuish, C., 2000, Werger, B-B., Mataric, M. J., 2000). We build on our previous work - the hardware implementation and basic control of robots - and we would like to achieve higher level control of the game strategy. The rest of the paper is organized as follows: First we briefly describe the base hardware and software implementation. Then we describe the representation of the game field using virtual grids. Then we describe possible game strategies. Using the virtual grids and game strategies, we show how to learn rules that describe particular game strategy. We conclude with the discussion of the presented approach.

2. BASE IMPLEMENTATION

The game system can be described as up to twice eleven autonomous mobile robots (home and visiting players), which are situated at the field of the size of 280x220cm. The core of each of our mobile robots is digital signal processor Motorola DSP56F805. The higher level of control system is represented by personal computer. The PC receives a view of the playing field from the CCD camera as an input, and gives commands to the mobile robots as an output. The software part is implemented by decision making and executive agents. The agents corresponding to individual robots are controlled by a higher level agent (Srovnal, V., Pavliska, A., 2002, Obitko, M., Snasel, V. 2004, Smid, J., Obitko, M., Snasel, V. 2004). The task of conversion of the digital image into the object coordinates is solved separately. The coordinates are saved in the scene database (Bernatik, R., Horak, B., Kovar, P., 2001), which is common for all agents. Both agent teams have a common goal — to score the goal and not to get any goal. For a success, it is also important to extract the strategy of the opponent team. The extraction and knowledge of opponent game strategy is an approach that is known to be successful in other situations as well (Slywotzky, A.J., Morrison, D., Moser, T., Mundt, K., Quella, J., 1999).

3.GAME REPRESENTATION - VIRTUAL GRID

The game can be represented as a trajectory in what we call the virtual grid. The virtual grid generally allows us to reduce data volume for easy description of player motion and subsequently for controlling the game or for learning game strategies. The natural coordinate system is provided by accurate optical sensing of the subject position using lens for optical transformations and the CCD camera. This natural coordinate system can be easily mapped to a virtual grid. A sample picture before processing is shown in the figure 1. The data volume of the description using the virtual grid is obviously smaller than the description using natural coordinates. The exact values depend on the frequency of samples, i.e. on the used CCD camera (typically 25-75 fps) and on the maximal velocity of the mobile robot movement at game field (typically up to 2,5m/s). The dimensions of the *primary* virtual grid are determined by the possible distance of the robot position in two subsequent frames from the CCD camera. The primary virtual grid can be divided to more (2, 4, 8, . . .) parts, which creates *secondary* virtual grid (in next SVG). Using the virtual grid, it is possible to describe the position and direction of the robot using an alphanumeric description. This description is illustrated in the figure 2 - let us explain the notation on the example description [G1HA24HC24]. The first letter describes the role of the player — attacker (A), goalkeeper (G) and defender (D). The second number is an index of the player with the given role in the team (i.e. 1, 2, . . .).

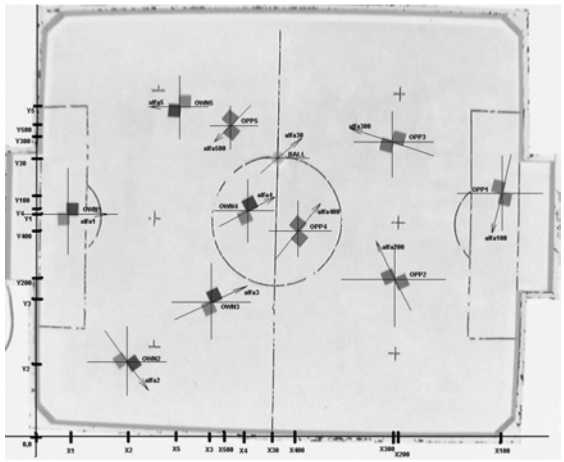

Fig. 1. Sample of the game field with marked positions.

The next two letters and two numbers represent the current position of the player on the field - here, the position is HA24 (see the figure 2). The last two letters and two numbers describe the planned movement, i.e. the planned position in the next moment. The tercial grid — *strategy* grid — depends on the partition of the game field (the left-right wing, the central field, and transversely the attack-defense field and the central field). In the discrete frame samples it is possible to study movements and movement strategies of the robots.

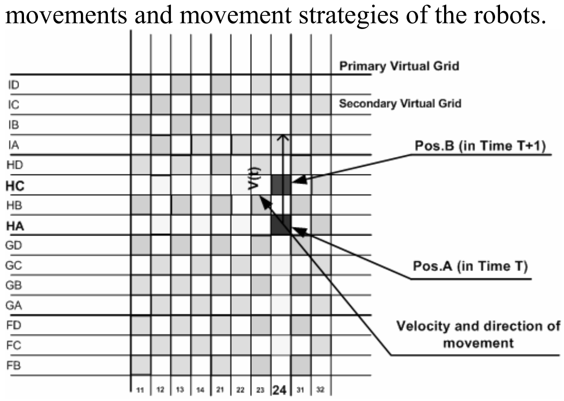

Fig. 2. Alphanumeric representation of robot position and movement using virtual grid —[G1HA24HC24].

4. GAME STRATEGY

The game strategy can be dynamically changed based on the game progress (i.e. the history and the current position of the players and the ball). The game progress can be divided in time into the following three ground playing classes (GPC):

- GPC of game opening (GPCO)
- GPC of movements in game site (GPCS)
- GPC of game end (GPCE)

The game progress, especially in the GPCS class, can be also divided into the following two game playing situations (GPS):

- GPS of attack (GPSA). The interactions of simple behaviors cause the robots to fall into a V-formation where the ball is in motion roughly towards the opponent's goal.
- GPS of defense (GPSD). When the ball is not moving roughly towards the opponent's goal, the robots move around it to form an effective barrier and to be in a good position for recovery.

Each GPC has its own movement rules. The classes GPCO and GPCE consist of finite number of possible movements that are determined by initial positions of players and the ball. The class GPCS has virtually unlimited number of possible movements. The movements are determined by the current game situation (GPS) and by the appropriate global game strategy (in next GGS). The movement of the particular robot is determined by the current game class and situation, and also by the robot role. For example, the goalkeeper's task is to prevent the opponent to score a goal. His movements are in most cases limited along the goalmouth near of goal line. The preferred movements are in goal line direction. The preference of these movements comes from the particular GGS, where the goalkeeper prevents to score a goal in the way of moving in the position between the central goal point and the ball (or the expected ball position). The preference of other movement directions is created using GPSA, where the movements of goalkeeper secure kicking the ball from the defense zone.

5. LEARNING GAME STRATEGY FROM OBSERVATION

In this section we describe our approach for learning game strategy from observation. Our goal is to learn an abstract strategy. The main steps of the learning process are:

- Transformation of observations into virtual grids.
- Transformation of observations into strategy grids.
- Learning a strategy based on the observed transitions between the strategy grids.

We adopt definition of strategy (Johnson, G., Scholes, K., 2001): *"Strategy is the direction and scope of an organization over the long-term: which achieves advantage for the organization through its configuration of resources within a challenging environment..."*

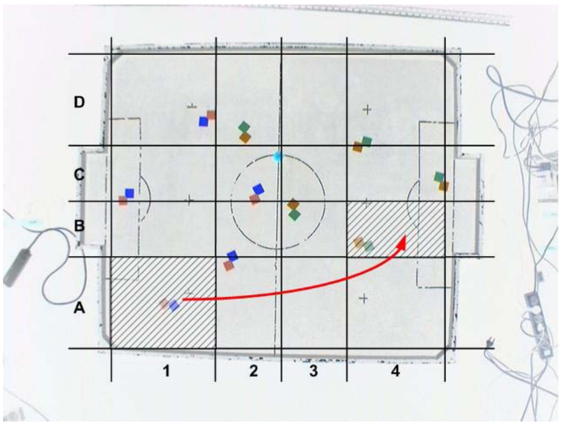

Fig. 3. Example of movement in the strategy grid.

In addition to this definition, we adopt the strategy grid for the description of strategy. The strategy grid has the same dimension as the virtual grid. We define strategy as movements in strategy grid. In this grid, the ground playing situations (GPCO, GPCS, GPCE, GPSA, GPSD) can be easily observed. For learning a strategy from observation, a game space reduction is needed. Game space reduction is the transformation from virtual grid to strategy grid.

6. BASIC DESCRIPTION OF STRATEGY SELECTION PROCESS

Strategy application for one movement of players is computed in following steps:

- Get coordinates of players and ball from camera
- Convert coordinates of players into strategic grid
- Convert ball and opponents' positions into virtual and strategic grids
- Choose goalkeeper and attacker, exclude them from strategy and calculate their exact positions.
- Detect strategic rule from opponents' and ball positions

- Convert movement from strategic grid to physical coordinates
- Send movements to robots

Each strategy is stored in one file and currently consists of about 50 basic rules.
Furthermore the file contains following metadata:

- Information about the name of strategy
- the algorithm to strategy choosing
- the author responsible for current strategy
- the date of last modification
- the size of strategic grid
- strategic rules

Each rule consists of five records:

- The rule ID and description (e.g. *Rule 1 "desc"*),
- the coordinates of our players in strategic grid (e.g. *.Mine a5 a5 a5 a5 a5*),
- the coordinates of opponent's players in strategic or virtual grid (e.g.*.Opponent k5 j2 i5 h7 i8),*
- the ball coordinates in virtual or strategic grid (e.g. *.Ball j8*)
- strategic or virtual grid positions of the move (*.Move a5 i4 g5 i6 j8*).

In current algorithm, the *.Mine* coordinates are not important for movement rule selection, but they can be used in the future. We believe that the file system for strategies is an advantage. From observation of opponent's strategy a new set of rules can be written, without necessity of program code modification. Furthermore, there is a possibility of automatic strategy (movement) extraction from running game.

.Strategy	**test 1"**
.**Author**	**"Vaclav Snasel"**
.Date	**"1.5.2004"**
.Size	**10 8**

.Rule 1 "Attack1"

.Mine	a4 b3 c1 d1 d4
.opponent	a2 b3 c2 d3 d4
.Ball	a1
.Move	a4 b3 c1 d1 d4

.**Rule 2 "Attack2"**

.Mine	a4 b3 c11 d1 c10
.Opponent	a2 b3 c2 d3 a1
.Ball	a1
.Move	a4 b3 c1 d1 a11

There exist two main criteria in the Strategy selection process. The selection depends on opponents' coordinates and ball position. The strategy file contains rules, describing three possible formations suggesting danger of current game situation. The opponent's team could be in offensive, neutral or defensive formations. Furthermore, we need to weigh up the ball position risk. Generally, opponent is not dangerous if the ball is near his goal. The chosen rule has minimal strategic grid distance from current configuration of players and ball.

Optimal movements of our robots are calculated by applying minimal distance from strategic grid position and rotation penalty. The goalkeeper and attacking player, whose distance is closest to the ball are excluded from strategic movement and their new position is calculated in exact coordinates.

To summarize, the strategy management can be described in the following way:

- Based on incoming data from the vision system, calculate virtual and strategy grid
- Coordinates of the players and the ball.
- The virtual grid is then used to decide which player has to control the ball.
- This player is issued a ”kick to” command that means that it has to try to kick the
- Ball to a given strategy grid coordinates.
- All other players are given (imprecise) ”go to” coordinates. These coordinates are
- Determined by the current game strategy and are determined for each robot individually.

The goalkeeper is excluded from this process since its job is specialized, and does not directly depend on the current game strategy.

7. CONCLUSION

The main goal of the control system is to enable immediate response in the real time. The system response should be shorter than time between two frames from camera. When the time response of the algorithm exceeds this difference the control quality deteriorates. The method we described provides fast control. This is achieved by using rules that are fast to process. We have described a method of game representation and a method of learning game strategies from observed movements of players. The movements can be observed from the opponent’s behavior, or e.g. also from the human player’s behavior. We believe that the possibility of learning the game strategy that leads to a fast control is critical for success of the robotic soccer players. Like in chess playing programs (Pachman

L., Russell A., S. 1971), the database of game strategies along with the indication of their success can be stored in the database and can be used for subsequent matches.

8. ACKNOWLEDGEMENTS

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