Potential Field Approach to Short Term Action Planning in RoboCup F180 League

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Abstract. We propose a potential field approach to represent a game situation. In a potential field, a ball should be moved according to the gradient of the potential field. There are three kinds of potential fields. One is defined for a game field, and another is defined for each robot. The third field is defined as the combination of these two. The combined field is used for evaluation of a situation. We applied this method to our robot control program. Potential values are used to determine the direction in which a robot kicks a ball. We compared the potential field based strategy and an usual "if then" type rule based strategy. The potential field based strategy makes better decisions in several cases and no worse decisions than the rule based strategy.

1 Introduction

Planning actions in dynamically changing game situations is difficult. Game situations have wide variety, so writing down the actions for each situation is unrealistic. As an alternative method, action planning based on the parametric representation which is generated from some calculation is necessary.

In robotics, a potential field method has been used for obstacle avoidance and path planning [1][2]. Effect of the potential is similar to the potential energy in physics. In robotic soccer, the situation of a game changes quickly, so fast calculation is more important than precise representation. SPAR [3] obtained similar effectiveness as the potential field approach. It does not calculate a potential field directly, but executes other parametric calculations and decides the position of each robot.

We propose a potential field approach to represent a game situation. Since the potential model is simple, the calculation speed is fast enough to deal with the changes in the real world. In the potential field, a ball should be moved from its present position to the points with lower potential.

We integrated the potential field into our robot control program. In our current strategy, the direction in which a robot kicks a ball is determined from the potential field. It was only used for the local and short term action. We compared the potential field based strategy and our usual "if then" type rule based strategy. While the potential field based strategy showed as good competence as the rule based strategy as a whole, it showed good decisions in several cases.

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2 Potential Field

We define a basic potential field P formed by an object in the soccer field. It is calculated by the next equation.

$$P = \frac{e}{r^n} \tag{1}$$

e indicates the "energy" of the object. The energy is a peculiar constant value defined for various objects, like an electrical charge in an electric field. r indicates the distance between the object and the point in the field where the potential is calculated. This equation is similar to the calculation of an electric field except the lack of constant term and the difference of value n. We determined n to $1/2$, considering the expanse of the potential field.

We define three kinds of potential fields. One is defined for whole field, and we call this the "Static potential field". Another is defined for each robot, and we call this the "Local potential field". The third field is defined as the sum of these two, and we call this the "Dynamic potential field". We indicate these three potential fields as P_S, P_L and P_D, respectively.

2.1 Static Potential Field

Static potential field P_S gives the potential of both our team's goal and the opponent's goal. Our goal has energy $+g$ which is the highest value in the field, while the opponent goal has energy $-g$ which is the lowest. We determined g to be 5, considering the expanse of the potential field around the goals. The static potential field is sum of the potential about our goal and the potential about the opponent's goal. Fig. 1(left) shows the static potential field. The x and y axises display the size of the game field, while the z axis displays a potential value. The sizes 280cm and 160cm are almost equal to the sizes of actual game field. The potential is varying from our goal to the opponent's goal gradually. The contours of the potential are drawn under the potential surface. In front of each goal, the contours spread in a radial pattern. Potential which is more than 1.0 and less than -1.0 are rounded to 1.0 and -1.0, respectively. This aims to give the same potential level to the whole goal area. The static potential field does not vary throughout the game.

2.2 Local Potential Field

Local potential field P_L gives the potential of each robot. It has a special form as shown in Fig. 1(right), that is, it has an e/r^n form for our goal side and a $-e/r^n$ form for the opponent's goal side. Energy e is set to 1. Both teams' robots have the same energy model. Calculation of the local potential is the same as the static potential field. The effective area of potential is limited to the inside of a certain circle. The radius of the circle is 10cm. The local potential field is given around each robot. The form of it does not vary, but it moves in the soccer field according to the movement of the robot.

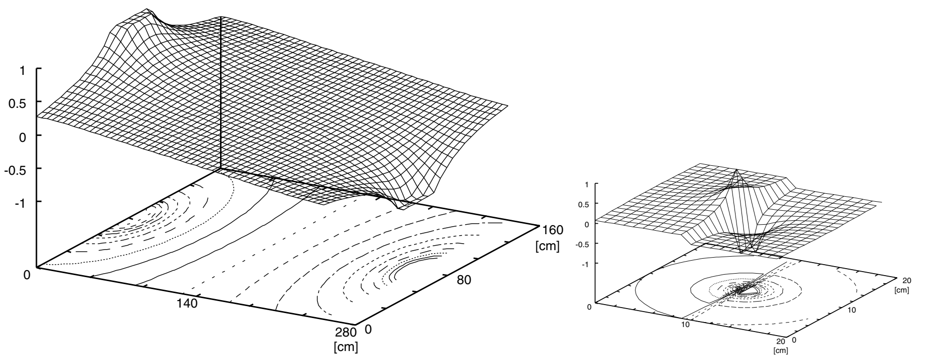

Fig. 1. Static potential field (left) and local potential field (right)

The reason why a robot has the special potential form is as follows. When a ball is placed at back side of our robot (Fig. 2 (a)), it can not kick the ball forward unless it moves to the back side of the ball. But when the ball is in front of the robot (Fig. 2 (b)), it can kick the ball immediately. Therefore the position (b) is preferable than the position (a) for our robot. When the ball is in front of an opponent's robot (Fig. 2 (c)), it can kick the ball immediately. This case is undesirable for our team. Case (d) is little better than case (c). Unifying these results, when the ball is placed at our goal side ((a), (c)), it is undesirable. When the ball is placed at the opponent's goal side ((b), (d)), it is desirable. The shape of local potential field reflects these facts.

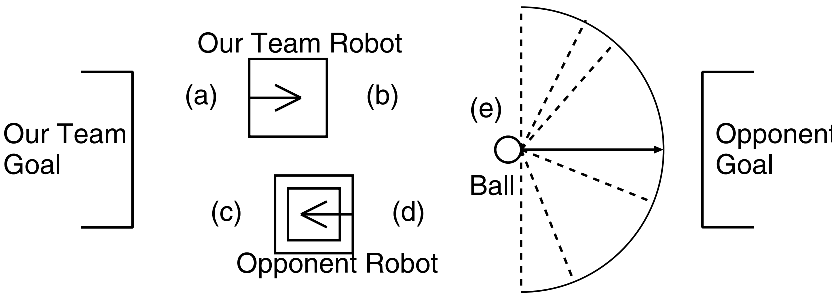

Fig. 2. Front side and back side of robots. (a) to (e) display different ball positions.

2.3 Dynamic Potential Field

Dynamic potential field P_D is given as the combination of P_S and P_L.

$$P_D = P_S + \sum P_L \qquad (2)$$

Fig. 3 shows an example of the dynamic potential field. Some peak points of the local potential fields are not drawn correctly, because of the rough sampling of drawing points. All robots are moving in real time, so that the dynamic potential field should be frequently recalculated to reflect the latest situation.

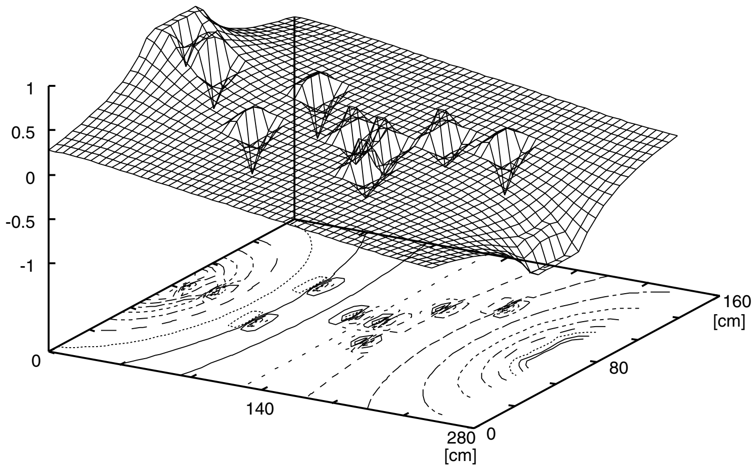

Fig. 3. Dynamic potential field

3 Strategy

3.1 Usual Rule Based Strategy

We are developing the robot control system in team Owaribito [4], which participates in RoboCup F180 League. Our team has used a "if then" type rule based strategy so far. Examples of the rules are as follows.

```
if (NEARMYGOAL == BallArea()) Clear();
if (NEARENEMYGOAL == BallArea()) Shoot();
if (SIDE == BallArea() && NEARENEMYGOAL == BallArea()) Centering();
if (YES == NearestBallPlayer()) PressBall();
```

These are the rules for the robots which approach the ball. The rule set has a hierarchy, like global strategy, an action of a robot, and a low level movement description. The robot control program analyzes the present situation and decides the next action of each robot. Our strategy program also realized a dynamic role change mechanism. It dynamically switches the role of each robot while considering the game situation. For example, two robots which are close to the ball play as midfielders(MF) try to control the ball everytime. Other robots become a forward player(FW) and a defender(DF), and help the MFs. The roles like MF, FW, DF are determined only from the positions of robots.

3.2 Integration of Potential Field into Strategy

We integrated the potential field into our robot control program. Dynamic potential field is used to determine the direction of kick. The potential field is not used for the dynamic role changing at present. The gradient of the potential field is examined around the ball every 10 degrees from −90 degree to 90 degree. The searching area is a half circular shape as shown in Fig. 2(e). The most descending direction is selected.

When a robot stands in front of the ball, the gradient value increases there. In such a case, the direction is not selected, and the most descending direction is selected instead. If some robots are surrounding the ball, the area in which no robot stands will be selected. As a result, the ball is carried to the open space where the opponent robots can not get the ball easily.

Most of strategy is the same as the usual rule based strategy including dynamic role changing, except for the decision of the kick direction using the potential field. Kicking a ball appears quite many times in soccer games, and it is a main part of all plays. The control of kicks is the basis of the strategy.

4 Evaluation

We compared the potential field based strategy and our usual rule based strategy in a soccer simulator. This simulator was developed for verification of strategies.

Although the scores of the games did not show a clear difference, the potential field based strategy showed good decisions in several cases. Fig. 4 shows snapshots of the game. In this figure, the single line boxes indicate our team's robots and the double line boxes indicate opponent robots as shown in Fig.2. Small black boxes indicate the tracks of ball movements. Fig. 4(left) shows the example of play. In this case, three opponent robots were surrounding the ball. Our robot 3 reached and kicked the ball upward. At next moment other robot kicked the ball to the right, and robot 4 could receive the ball. Fig. 4(right) shows another example. In this case, three opponent robots were surrounding the ball. Opponent robot 3 was little behind, so that our robot 4 could kick the ball downward and overtake the opponent robots. In both cases, the rule based strategy could not select the adequate kick direction due to the complexity of situation.

We sometimes observed these plays in the games. This result shows that the potential field based strategy can select the kick direction adequately. To obtain the same level of adaptivity by the rule based strategy, a complex rule set will be needed.

We measured the calculation speed of the potential field based strategy. It was carried out on a PC which has a Pentium II 300MHz processer. A calculation rate of over 200 cycles/sec was achieved. One cycle includes all of the potential field recalculation and all of the strategy decision. The potential field is currently calculated as a fine mesh with intervals of 1cm. In actual robot control, image processing is also needed. But it is confirmed that the calculation of the strategy is sufficiently fast.

In the team Owaribito, robot hardware and radio communication have almost been accomplished. But image processing of global vision is not accomplished yet. Therefore evaluation of the strategy on real robots is in progress.

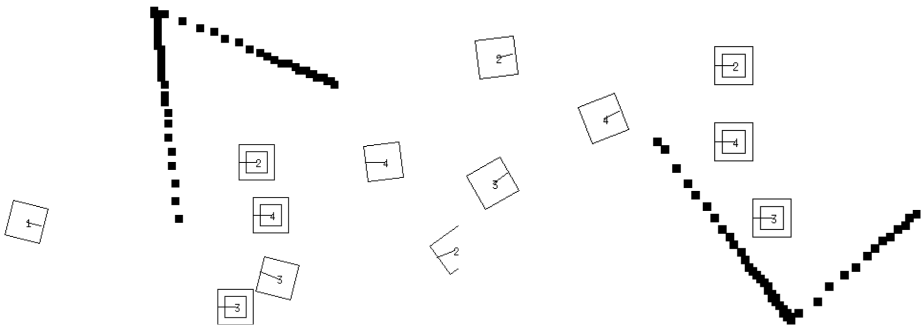

Fig. 4. Examples of play derived from potential field

5 Conclusion

We proposed a potential field approach to represent a game situation. There are three kinds of potential fields, the static potential field, the local potential field and the dynamic potential field.

We applied this method to our robot control program. We compared the potential field based strategy and an usual "if then" type rule based strategy. The potential field based strategy made better decisions in several cases and no worse decisions than the rule based strategy. We confirmed that the potential field based strategy can select the adequate kick direction. It is the merit of this method that the good adaptivity is obtained without making a complex rule set. We measured the calculation speed of the strategy, and it was sufficiently fast.

At the present time, the potential field is not applied for the team play like robot position control or passing a ball to a team mate. Applying the potential field to the team play and the long term global strategy is the future work.

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