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Path Planning Research of Robot Soccer Based on the State Transition Matrix

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Abstract: In robot soccer simulation game, in order not to collide with other robots and intercept the ball with the shortest distance, path planning for each player is a must. Mobile robot path planning is to find a collision-free and the most satisfying path from the starting point to the target point within a bounded and stumbling space. There are certain difficulties in the implementation of traditional research methods to this problem, for simple algorithm and in order to solve the desired goal, this study studies current state and attitude our players, football and other players in robot soccer simulation game, establishes a state transition matrix model which restored the conversion process between the two states both from the covered point and better security but due to the state transition matrix elements in the original state the algorithm have a certain degree of complexity. Therefore this study puts forward methods of sparse matrix and unit values quantification to improve the established model, although the improved model is slightly lower than the previous model in accuracy but it does not affect the accuracy; the implementation time of the algorithm have been greatly improved which wins the opportunity for path planning time of the players namely the decision time.

Key words: State transition matrix, augmented state, sparse matrix, robot soccer

INTRODUCTION

Motion planning is a very important area in robotics; the technology can not only improve athletic ability of the robot but also can make the robot safely and efficiently serve humanity. Path planning is one of the core issues in the field of intelligent robots; robotics is also an important study aspect in the artificial intelligence. The correct path planning and accurate obstacle avoidance is an important manifestation of intelligent robot; the robot motion planning focuses on how to drive a robot automatically and safely transform from one state to another state and has its very important meaning in the scientific research, economic and military. So scientists at home and abroad conduct in-depth study on this issue and have made great progress in algorithm design, algorithm analysis and simulation tests. In the robot soccer game, sometimes the goalkeeper will be out of the active area by the other side’s players (Yue and Yuan, 2011); in this case, the robot goalkeeper will return to its safety zone to ensure the goal is safe as soon as possible but the door area is a more dangerous zone, with unreasonable path planning there may appear the goalie kick own goal phenomenon. Similarly, when our players want to shot, the other defensive players will inevitably intercept the ball but in the confrontation course of the two sides the collisions between players is inevitable. Based on the above conditions, if we can plan the motion paths for the soccer robot, then we can avoid these two poor results and this study uses the state transition matrix model to study the problem (Yi and Liu, 2010).

For the path planning problem of robot soccer and research the state transition matrix models many people have made efforts, their efforts provide a theoretical foundation and forward vision for robot technology development and the application platform of state transition matrix, including: Wu (2011) from Electrical and Mechanical Information Branch of Yiwu Business Technology Institute in "Soccer Simulation of Robot Path Planning", studied the path optimization selection problem of soccer robot, for the problems of traditional robot path planning algorithm was too complex and did not fully consider the real time and confrontation in the robot soccer game, proposed the path optimal algorithm combined with path prediction, algorithm to predict fully used the prediction results to reduce cyclical path planning time, used the shot strategies of dynamic baseline forecast and improved the strategies of goalkeeping, the simulation results showed that the proposed algorithm is feasible in the simulation game and shooting accuracy has been improved (Wu, 2011); Duan Jun-hua, Li Xiao-an and Liu Liyun from Computer Science School of Northwestern Polytechnical University in "the application of artificial potential field in soccer robot path planning", for the shortcomings and deficiencies of the artificial potential field method in the applications of robot soccer competition platform, summarized the principles of artificial potential field method and the representing methods of several different potential functions, explained the variety of improved algorithm in current domestic and abroad and the applications combined with other methods, focused on studying the applications and improvements of artificial potential field method in robot soccer competition platform and made several prospects on the future work (Tang and Yang, 2003; Song *et al*., 2009) from Engineering College of Ocean University of China (Song *et al*., 2009) from Computer Network Center of Heilongjiang Electric Power Staff University and Shen Wen-qing from Marketing Company of Shandong of China Petroleum, in the "Shooting path planning for soccer robot based on dynamic ellipse curve", in order to improve shooting success rate in robot soccer game, the study proposed a shot path planning algorithm based on the dynamical elliptic curves, by calculating the current posture of soccer robot and the expected shooting angle, controlled the robot to move to the goal shot point following the path of elliptic curve, achieved fast and effective shots, the simulation and real robot experiments verified the effectiveness of the algorithm, in the shot planning algorithm of dynamic elliptic curve the motion path is short and can complete shot in a reasonable shooting angle (Song *et al*., 2009); Feng Tie-ying and Jia Ji-kai from School of Public Policy and Management of Xi'an Jiaotong University, in the "The sustainability research on basic pension insurance system for urban employees based on the state transfer matrix model", used the theoretical method of systems engineering, by constructing the state transition matrix model quantitatively analyzed the influence mechanism of the" population - rural and urban-age" structural linkage on the sustainability of urban basic pension insurance system, based on the model deduced results and the study conclusions, the study put forward some relevant countermeasures and suggestions to achieve the sustainable development of the basic pension insurance system for urban workers; (Liu and Zhu, 2010) from Resources and Environmental School of China Agricultural University, in the "Methods for Detecting Land Use Changes Based on the Land Use Transition Matrix", based on the transition matrix of the land use, constructed the calculation method of net variation of land using, the exchange variation and the total variation and calculated the theoretical frequency of converting between classes in random states, by comparing the conversion amount of time and the theoretical conversions, constructed methods to judge the land use and the conversion rules, thus clearly judged the system process of land use change. (Liu and Zhum, 2010)

By improving its effect the method has no apparent decline but the computer-implemented simulation time has significant changes, that is to say the improved model method described in the text is able to reduce the decision-making time under the premise of meeting the actual accuracy needs. Table 1 shows the comparison results of 20 experiments and the results each time select the total numbers of hitting ball over 300 times.

This study studies the path planning problem of soccer robot based on previous studies, in the robot soccer path planning a study to establish the state transition matrix model, improves the algorithm after studying the complexity of the model algorithm; under the premise of not affecting the accuracy, the algorithm implementation time of the algorithm after improvements has made significant breakthroughs compared to algorithm before improvements.

PATH PLANNING PROBLEM OF SOCCER ROBOT

In the robot soccer game, sometimes the goalkeeper will be out of the active area by the other side's players; in this case, the robot goalkeeper will return to its safety zone to ensure the goal is safe as soon as possible but the door area is a more dangerous zone, with unreasonable path planning there may appear the goalie kick own goal phenomenon.

The purpose of the robot motion planning is to solve a problem of robot as how to automatically and securely transform from one state to another state; for simulation system composed of more than one robot soccer, many of its path planning studies are NP-hard or even PSPASE-hard problem; even if this is the currently fastest computer cannot get a good solution.

In this study, taking into account the above factors, it studies the path application for the robot soccer using the method of state transition matrix and conduct simplification and improvement on the basis of the original model.

PATH PLANNING BASED ON THE STATE TRANSITION MATRIX

Transition matrix model: The control of robot soccer is determined by the venue's geometry size and shape, the movement parameters of our players are the controllable object; the target position, speed, direction of movement all can be measured; so that the control can have real-time and deterministic property. In the five-on-five robot soccer competition, under normal circumstances robot soccer vision system needs to identify a target, if we use R to represent our players, the subscript represents the player's number, use r to denote the other side's players, the subscript indicates the player's number, use B to denote football, X,Y means Cartesian coordinate, θ represents the direction angle of movement, the player's posture is considered as a state, each current status can be represented by the Eq. 1:

$$S^{n}\left(R_{1n}X,R_{1n}Y,R_{1n}\theta,R_{2n}X,R_{2n}Y,R_{2n}\theta,\cdots,R_{5n}X,R_{5n}Y,R_{5n}\theta\right) \tag{1}$$

For the current state S^n of the Eq. 1 it must have its optimal next state S^{n+1}, times for the transform of the current state to the optimal next state needs the role of the state transition matrix, the matrix design is the basic unit to implement path planning. The credit state of all target position is in the Eq. 2 below:

$$Q^{n}\begin{pmatrix} R_{1n}X,R_{1n}Y,R_{1n}\theta,R_{2n}X,R_{2n}Y,R_{2n}\theta, \\ \cdots,BX,BY,\cdots,r_{5n}X,r_{5n}Y,r_{5n}\theta \end{pmatrix} \tag{2}$$

By Equation 2 the controllable state component S^{n+1} of every state can determine an optimal value through the current credit status Q^n.

Suppose the player's maximum speed is V_{max}, the maximum angle is ω_{max}, R_i X, R_i Y means our players' Cartesian of the controlled object, θ_i means the orientation angle, T means the time interval from the current state to the second state, then the constraint of line speed is shown in Eq. 3:

$$\frac{\sqrt{\left(R_{i(n+1)}X-R_{in}X\right)^{2}+\left(R_{i(n+1)}Y-R_{in}Y\right)^{2}}}{T}\le V_{max} \tag{3}$$

Condition of the angular velocity is shown in the Eq. 4 below:

$$\frac{\theta_{i+1}-\theta_{i}}{T}\le \omega_{max} \tag{4}$$

Introducing state matrix A_{mxn} as shown in Eq. 5 below:

$$A_{m\times n}=\begin{pmatrix} a_{11} & \cdots & a_{111} \\ \vdots & \ddots & \vdots \\ a_{51} & \cdots & a_{511} \end{pmatrix}_{5\times 11} \tag{5}$$

Based on the above analysis, the component of each state can be represented by the Eq. 6 below:

$$\begin{pmatrix} R_{1(n+1)}X \\ R_{2(n+1)}X \\ R_{3(n+1)}X \\ R_{4(n+1)}X \\ R_{5(n+1)}X \end{pmatrix}=\begin{pmatrix} a_{11} & \cdots & a_{111} \\ \vdots & \ddots & \vdots \\ a_{51} & \cdots & a_{511} \end{pmatrix}_{5\times 11}\begin{pmatrix} \sum_{i=1}^{k} b_{1j}R_{1n}^{i}X+\sum_{i=1}^{k} c_{1j}R_{1n}^{i}Y+\sum_{i=1}^{k} d_{1i}R_{1n}^{i}\theta \\ \sum_{i=1}^{k} b_{2j}R_{2n}^{i}X+\sum_{i=1}^{k} c_{2j}R_{2n}^{i}Y+\sum_{i=1}^{k} d_{2i}R_{2n}^{i}\theta \\ \sum_{i=1}^{k} b_{3j}R_{3n}^{i}X+\sum_{i=1}^{k} c_{3j}R_{3n}^{i}Y+\sum_{i=1}^{k} d_{3i}R_{3n}^{i}\theta \\ \sum_{i=1}^{k} b_{4j}R_{4n}^{i}X+\sum_{i=1}^{k} c_{4j}R_{4n}^{i}Y+\sum_{i=1}^{k} d_{4i}R_{4n}^{i}\theta \\ \sum_{i=1}^{k} b_{5j}R_{5n}^{i}X+\sum_{i=1}^{k} c_{5j}R_{5n}^{i}Y+\sum_{i=1}^{k} d_{5i}R_{5n}^{i}\theta \\ \sum_{i=1}^{k} b_{6j}B_{n}^{i}X+\sum_{i=1}^{k} c_{6j}B_{n}^{i}Y+\sum_{i=1}^{k} d_{6i}B_{n}^{i}\theta \\ \sum_{i=1}^{k} b_{7j}r_{1n}^{i}X+\sum_{i=1}^{k} c_{7j}r_{1n}^{i}Y+\sum_{i=1}^{k} d_{7i}r_{1n}^{i}\theta \\ \sum_{i=1}^{k} b_{8j}r_{2n}^{i}X+\sum_{i=1}^{k} c_{8j}r_{2n}^{i}Y+\sum_{i=1}^{k} d_{8i}r_{2n}^{i}\theta \\ \sum_{i=1}^{k} b_{9j}r_{3n}^{i}X+\sum_{i=1}^{k} c_{9j}r_{3n}^{i}Y+\sum_{i=1}^{k} d_{9i}r_{3n}^{i}\theta \\ \sum_{i=1}^{k} b_{10j}r_{4n}^{i}X+\sum_{i=1}^{k} c_{10j}r_{4n}^{i}Y+\sum_{i=1}^{k} d_{10i}r_{4n}^{i}\theta \\ \sum_{i=1}^{k} b_{11j}r_{5n}^{i}X+\sum_{i=1}^{k} c_{11j}r_{5n}^{i}Y+\sum_{i=1}^{k} d_{11i}r_{5n}^{i}\theta \end{pmatrix} \tag{6}$$

In Equation 6 the element value of the matrix and the element coefficient value of the right matrix is derived from the computer simulation, of course, we can also manually select some representative states and analyzes to determine the optimal next state, then substitute these current status and optimal next state into the matrix equation and obtain each factor and the relationship of next-state and the augmented state.

Based on the above analysis we can obtain the expressions of S^{n+1} on Q^n, thus we can see the accuracy of the path planning depends entirely on the size of the K value but the size of value K also determines the complexity of the operation (Zhang, 2013).

The components that effect state largely are the Cartesian coordinate values of our players, the direction of motion of our players, the ball's location and its direction of movement; while the other player's position is less important, especially the movement direction of the other players; so in order to reduce the amount of computation, the coefficient of the movement direction of the other players can be set to zero.

Improved state transition model: Seen from the analysis there are too many original states, it has greater difficulty in achieving manual handling or computer simulation. The original state is distinguished according to the pixel, the image sample for each time interval by the computer is a discrete section with a plurality of pixels and these are the causes of excessive original states.

This study uses the Coordinates sparse way to achieve the status merger and reduce computational complexity, so make it convenient for the machine simulation; the sparse method is divide the actual coordinates (X, Y, θ) by a unit value, suppose the unit values are, respectively l, a, then the coordinates after the sparse is in the Eq. 7 below:

$$(X_d, Y_d, \theta_d) = \left(\left[\frac{X}{l}\right], \left[\frac{Y}{l}\right], \left[\frac{\theta}{\alpha}\right]\right) \tag{7}$$

In Equation 7 the bracket denotes rounding operation.

When the selected unit value is too large, due to the constraints of linear velocity and angular velocity render it impossible to transform state; if the selected value is too small, it will increase the difficulty of computational complexity and computing simulation, so the unit value should be selected considering the above two situations. For the selection of unit values in Cartesian coordinates we should also consider the unit value must be less than the maximum moving distance between two adjacent images of the robot, according to the actual situation we can select l = 3; for the selection problem of θ, its value should be less than the maximum rotation angle in the two images of the robot. The maximum rotation angle should be the turned angle of the robot car whose two wheels move in the opposite direction simultaneously. Then the connection center of the two wheels is the instantaneous center, there is $\theta_{max} = 0.93$ rad but changes in angular coordinates are relatively small and the motion is more sensitive to the angle, the quantization unit of the angle is shown in the Eq. 8:

$$\alpha = \frac{\theta_{max}}{6} = 0.155\,\text{rad} \tag{8}$$

Therefore, the target's centroid falls largely in the state at range of:

$$[3i, 3j, 0.155k; 3(i+1), 3(j+1), 0.155(k+1))$$

And after the coordinates rarefaction, all states are merged into one state, wherein i, j, k is the integer of the definition domain.

When we have achieved state merge and determined the matrix coefficients, for each current state, the determined next state can be drawn, therefore: the current state is determined only by the last state and this state transfer does not impact next state transition, there is no cumulative error either, that is, the state transition process is a Markov process.

If we want to achieve more substantial state merger, the time interval of two adjacent images is selected as n T, thus the quantization unit can select greater value.

DATA ANALYSIS OF THE SIMULATION RESULTS

This study describes the path planning problem of soccer robot based on state transition. By improving its effect the method has no apparent decline but the computer-implemented simulation time has significant changes, that is to say the improved model method described in the text is able to reduce the decision-making time under the premise of meeting the actual accuracy needs. Table 1 shows the comparison results of 20 experiments and the results each time select the total numbers of hitting ball over 300 times.

From the data in Table 1, the errors of the success rate of hitting is minimum for the state transition matrix model before and after the improvement, the average error is-0.18% which is negligible; the running time of the algorithm after improvement has changed greatly, has reduced averagely about 26.74%.

CONCLUSIONS

This study establishes a path planning model of the robot soccer based on state transition matrix, this model well restores and simulates the transition process from the current state to the optimal next state of our players, football and other players in the game; on the basis of the original state transition matrix model, in order to reduce the complexity of the algorithm, it introduces the concept of sparse matrix and unit quantification which largely reduces the amount of computation; the improved algorithm is slightly lower than the algorithm before the improvement in the accuracy calculation but it has a great impact on the results and the improved algorithm has made significant improvements in the running time which is significantly better than the model algorithm before improvements.

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