Soccer Robot Path Planning based on Arc-cotangent Optimization Algorithm

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***Abstract*—To improve the success rate of soccer robot in competition, a method for robots path planning has been presented by analyzing shortcomings of basic shooting algorithm. By means of the differential and smoothness of the Arc-cotangent algorithm, the paper effectively solves the problem about how to find out the optimal path planning to avoid the obstacle from the certain point to the destination in real time. The simulation experiment indicates that the proposed method is capable of path planning, computationally undemanding and it is very practical.**

***Keywords*— Soccer robot; Arc-cotangent algorithm; Obstacle avoidance**

Ⅰ. INTRODUCTION

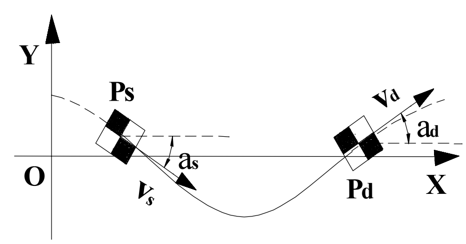
The robot soccer competition is a highly technological oppositional activity that has been developed in recent years. During the competition, the optional path planning of robots is the important part since the ways to plan the robots' paths and avoidance of robots from two sides crashing together unopposed are closely related to the victory of the competition. The optional path planning will directly influence the immediacy and accuracy of the action. So each researcher of soccer robots takes it as a focus. In the path planning, there are two common methods for robots to go to a destination: Turn-Run-Turn[1] and PID[2]. In Turn-To-Turn, the procedure goes as follows: The robot firstly turns to some angle, and then it runs to the destination and adjusts the angle to keep consistent with the destination. Because of the neglecting of the inertia, the robot may lean over the destination while adjusting the angle. What is more, after reaching the destination, it reacts at a low speed in considering the precision for it has the two processes of speeding up and slowing down. Undoubtedly, it must double the kicking time and delay the opportunity to win. In PID, although there has been an optical path to arrive at the destination, the barrier of the fellow robots during the moving process has not been taken into consideration, which may cause the crashing of some robots.

In the field of the path planning, as the path should be fit with not only the starting point and moving direction, but also the destination and its moving direction, we make use of the Arc-cotangent Algorithm, which has the characteristics of smooth, differential and satisfaction to any end and slope, to effectively solve the problem about how to find out the optimal path planning to avoid the obstacle from the certain point to the destination.The path planning problems in this paper can be divided in to three sub-points as following : 1)The search for the Arc-cotangent Algorithm function which satisfies the direction of endpoints and tangent lines ; 2)The crash-avoidance path planning ; 3) The optimal path planning of soccer robots。

Ⅱ. THE PATH PLANNING OF ARC-COTANGENT ALGORITHM

A .The Principle of The Arc-cotangent Algorithm Path Planning

It is supposed that the initial position Ps (xs,ys), the initial speed vs (the directional angle is as), the aimed position Pd (xd,yd) and the end speed vd (the directional angle is ad) are already known. Anyway, we can find a Arc-cotangent Algorithm from the initial position to the aimed position as is shown in Pic.1.



Pic.1 the Principle of the Arc-cotangent Algorithm Path Planning

$$y = k_1 arc\cot(k_2 x) \qquad (1)$$

The initial position Ps and the aimed position Pd are both on this algorithm. So:

$$y_s = k_1 arc\cot(k_2 x_s) \qquad (2)$$

$$y_d = k_1 arc\cot(k_2 x_d) \qquad (3)$$

As the speed directions of the algorithm vs or vd, which are at Ps or Pd, are the very directions of the algorithm's tangent, the following conditions are in need.

$$\left.\frac{dy}{dx}\right|_{x=x_s} = -\frac{k_1 k_2}{1+(k_2 x_s)^2} = \tan\alpha_s \qquad (4)$$

$$\left.\frac{dy}{dx}\right|_{x=x_d} = -\frac{k_1 k_2}{1+(k_2 x_d)^2} = -\tan\alpha_d \qquad (5)$$

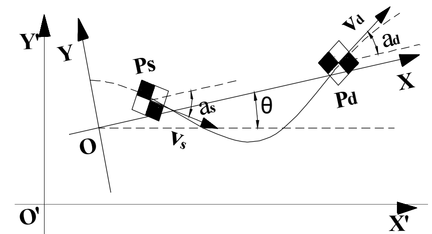
B . The Exchange of Coordinate

1). The definition of coordinate system

In the minisystem of Soccer Robot, the robot is moving on a bidimensional plane. By a vertical suspended camera we can get the view of the ground, and then we can describe the detailed position of robot by the bidimensional rectangular coordinate. There are some basic hypothesizes to define the coordinate systems to show the positions and postures of the robots.

a). The origin of court is located at the left lower corner of the court as is shown in Pic.2.

b). Hypothesis of right attack: our side is on the left, and we are trying to attack the right part; the fellow partners are on the right, and they are trying to attack our side; after changing the field, the visual information is changed, so our side is still on the left part and attacking right part. There is no influence on the movement control algorithm.



Pic. 2 the diagram of the position and posture of robots

There are definitions of coordinate systems as follows.

a). The court coordinate system: O'X'Y'.

The soccer robot introduced here is a mobile robot which does plain motion in an approximately rectangular court. In the basic coordinate system O'X'Y' which is based on the court, the robot barycentric coordinates (x', y') represent the position of the robot; the included angle a' between the positive direction and the X' axis refers to the position of the robot. Here the position of the robot P' is defined as:

$$P' = [x', y', a']^T \quad (6)$$

b). the movement locus coordinate system: OXY

As is shown in Pic.2, OXY takes the initial position of the robot as its origin, the axis of symmetry of the movement locus as OX axis. In OXY, the robot barycentric coordinates (x, y) represents the position of the robot; the included angle a between the positive direction and the X axis refers to the position of the robot. Here the position of the robot P is defined as:

$$P = [x, y, a]^T \quad (7)$$

2).The coordinate exchange of the court coordinate system and movement locus coordinate system

Suppose in the court coordinate system O'x'y', the random position of the robot is P [x', y', a']^T, , the accordingly P in the movement locus coordinate system is [x, y, a]^T . In fact Oxy is formed by the co-effort of a translation (T) and a revolving (R). The matrix of T and R is shown below.

$$T = \begin{bmatrix} 1 & 0 & x_O' \\ 0 & 1 & y_O' \\ 0 & 0 & 1 \end{bmatrix}, \quad R = \begin{bmatrix} \sin\theta & -\cos\theta & 0 \\ \cos\theta & \sin\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (8)$$

$$A = T \cdot R = \begin{bmatrix} \sin\theta & -\cos\theta & x_O' \\ \cos\theta & \sin\theta & y_O' \\ 0 & 0 & 1 \end{bmatrix} \quad (9)$$

So the position of the midpoint of movement locus coordinate system in the court coordinate system can be displayed as below.

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} \sin\theta & -\cos\theta & x_O' \\ \cos\theta & \sin\theta & y_O' \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} \quad (10)$$

And its position is:

$$a = a' - \theta \quad (11)$$

The information transferred through visual sub-system in the reality is the robot position [x', y', a']^T in the court coordinate system, which can be changed into the position [x , y, a]^T in the movement locus coordinate system by the transformation of the position and posture. Only the combination of (2), (3), (4), (5), (10) and (11) can make sure the value of k_1, k_2 and θ.

C . The Planning of Optimal Route

1).The optimal algorithm

In practical application, the working environment for mobile robots is usually complicated and inevitably there are obstacles among them. Therefore, if we seek for the curve function that satisfies the above boundary value conditions, we have to consider how to make the robot safely reach the target location without touching the obstacles on the way, namely the optimal path planning of soccer robots. With this descriptive method, such kind of problem is transformed into a series of non-linear minimal ones which are controlled by inequality conditions. This paper, on the basis of mathematic analysis, tries to solve the problem of path planning for incomplete controlled obstacles. One of the optimal mathematic methods is called compounding[3], which can be used to solve such problems. The characteristic of the method lies in its reliability in solving the low-dimensional questions. Besides compounding, other optimal methods can also resolve this kind of questions well, for example, genetic algorithm, neural network algorithm, annealing analog algorithm[4][5], etc. However, those algorithms are usually rather complex with huge calculating, so they are not appropriately applied in the situation of robots' path planning, which calls for synchronicity at a high level.

The following is the process of the resolving for the soccer robots' optimal path planning on the basis of Arc-cotangent Algorithm[6].

2). Target Function

In the soccer robot competition, the robots' movement locus often requires the minimal time and smoothness. Accordingly the target function is:

$$\sum = \min(1/N \cdot \sum_{i=1}^{N} |\delta_i| + \lambda(N/\widehat{N} - 1)) \qquad (12)$$

Here δ_i refers to the curvature of the robot movement locus in the i period[7]; N: refers to the needed number of the period before the robot get to the destination; $\widehat{N}$ refers to the least needed number of the period before the robot get to the destination; λ is weighting efficient.

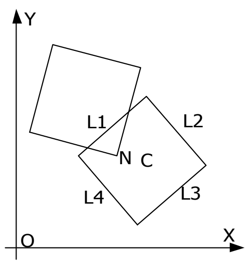
$$\delta(x) = \frac{|y''|}{(1+y'^2)^{3/2}} = \frac{|-k_1 k_2^2 \cos(k_2 x)|}{(1+k_1^2 k_2^2 \sin^2(k_2 x))^{3/2}} \qquad (13)$$

Arc-cotangent Algorithm is twice differentiable, which ensures that the target function is a continuous one.

3). Constraint Equation

Suppose the number of obstacles in the soccer robot's moving area is n, the constrained condition for all the obstacle area is expressed as follows:

$$G(x,y) = \sum_{i=1}^{n} g(x,y) \le 0 \qquad (14)$$



Pic.3 THE MODEL OF ROBOT CRASHING

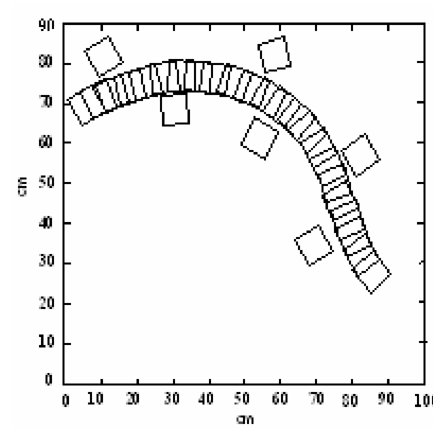
In the soccer robot competition the shape of the robot is a square with each side being L. During the competition, the crash is very frequent. Then five different situations are divided according to different paths, that is, different movement equations of two robots. One moves vertically, the other stable; both move vertically; one vertically, the other circularly; both circularly; one stable, the other moves circularly. Different treatment should be applied to different situation. When two robots get in touch with each other, their respective direction is at random, and everything is likely to happen. In order to simplify the situation, we suppose that every robot has four sides, and if two sides of the two robots intersect with each other, we can infer that the two robots crash into each other[8]. To be simple, we display the constraint function as follows.

$$g(x,y) = (x-x_0)^2 + (y-y_0)^2 - 2l^2 \qquad (15)$$

4). Design variables

From the analysis of the Arc-cotangent Algorithm equation we can learn that the planning locus is determined by the location of the destination and the two coefficients k1 and k2, because the position and initial speed are known to all. When the movement locus is known, the location of the destination can be directly learned from the needed number of period before the robot get to the destination. Therefore, the design variables in this paper is the number of the period N and the coefficient k1 and k2,

III. SIMULATION CASE STUDY



Pic.4 the simulation result of optimal avoidance of crashing

To testify the effectiveness of the above algorithm, the paper presents the following simulation experiment. Suppose the initial position of soccer robot is (7, 68, π/8), the destination position is (86, 28,-π/4). There are six dynamic obstacles in the environment with their respective position as (11, 82),(30, 64),(52, 61), (58, 84) , (69, 35) and (82, 57). They do uniform motion in a straight line at different speed respectively. The simulation result is shown in Pic.4.

IV.CONCLUSION

We make use of the Arc-cotangent Algorithm, which has the characteristics of smooth, slightness and satisfaction to any end and slope, to effectively solve the problem about how to find out the optimal path planning to avoid the obstacle from the certain point to the destination. In the process of the robot movement, the current position and the destination are changing all the time, and accordingly, the robot of the other side (the obstacle) is also changing. Thus, the movement locus of the robot should be replanned in every period. Finally the locus of the robot movement is no longer an arc cotangent curve, and instead, it is a curve which is smooth, continuous and irregular. From the simulation result we can learn that by means of arc cotangent curve, robot can effectively keep away from obstacles to get to the destination. What is more, it can ensure that every point in the planning path can satisfy the incomplete constraint conditions and design an optimal path to avoid crash. The optimal process is simple in structure, easy to calculate, accurate in result, fast at speed and is suitable for the dealing of the optimalization. Besides, it is superior in delicacy compared with emulation annealing and taboo search optimal algorithm. Thus it can be applied to those areas such as searching, exploring and aerospace. Decision-making system of soccer robot based on the Arc-cotangent has been successfully applied in the 2007 FIFA Cup China, and brought up the second-place of SimuroSot5vs5.

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