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Robot soccer target tracking algorithm research and analogue simulation

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ABSTRACT

Robot soccer system is proposed by Canadian, the purpose is to provide a kind of standard line service by using each kind of techniques so that to improve the field development. The paper based on the same purpose, it makes dynamics, kinematics and other correlation researches by using wheel mobile soccer robot and presents mechanical analysis, finally it verifies the model conforms to practice by applying analogue simulation way, so that build foundation for soccer robot undertakings development.

KEYWORDS

Soccer robot;
Analogue simulation;
Biomechanics;
Target tracking.

PREFACE

With era development, computer, control, electromechanics and other disciplines mutual combine, and after that it generates robot, it carries out research that focuses on information handling, control, kinematics and single chip, the paper formally researches robot soccer system under such background.

For robot soccer researches, formers have made many efforts, which makes indelible contributions to the undertaking development, such as: *Tambe*、*Veloso*、*Ki* tan *o* and other scholars from all countries in the world published correlation articles, they stated about robot soccer evaluation principle, research contents, present stage target and research's historical significance and so on, and put forward soccer robot development orientation in future development, that was: Regarding multiple intelligent cases, solved problems with uncertain scenes, and proposed that both space network software intelligent robot and practical world intelligent robot can be generally regarded as intelligent system with initiative, reactivity, sociality and independence so on; In addition, relative organizations in international about robot soccer have international robot soccer association and robot world cup joint conference, the two have corresponding competition events every year so as to promote relative field development.

The paper just on the basis of former researches, it carries out system research on soccer robot dynamics and others, and sets simulation to verify so that gets soccer robot each kind of model setting's rationality, it will provides impetus for intelligent field development.

SOCCER ROBOT MOVEMENT RESEARCH MODEL

With soccer development, robot soccer also accordingly maps into people's view, it is a kind of intelligent robot and artificial robot comprehensive item.

In order to define soccer robot concrete postures and position, the paper selects to use coordinate system to correct position, it can use three-dimensional space vector to position, but due to consider camera's limits, so the paper defines two-dimensional space, it is as following Figure 1 show:

By above Figure 1, it can make corresponding co-

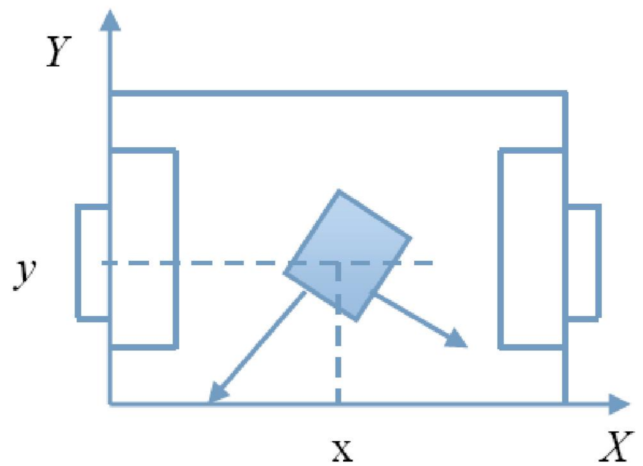

Figure 1 : Schematic description of the position and posture of the robot

ordinate system, that:

1) Use $O_r X_r Y_r$ or $\{R\}$ to represent soccer robot coordinate, above Figure 1 is taking soccer robot center point as starting point.

2) Use OXY or {F} to represent original coordinate system, above Figure 1 left bottom is original coordinate system's starting point, and add robot playing process visual information exchanging, then corresponding algorithm has no influences.

By above figure, we can define now soccer robot concrete position p_c and posture p :

$$\mathrm{P} = [x, y, \alpha]^T \quad \mathrm{P}_C = [x, y]^T$$

3) Use $\{v\}$ to represent pixel coordinate which is also called absolute coordinate, above Figure 1 top left corner is used as starting point coordinate point.

Soccer robot coordinates conversion

(1) Regarding vision coordinate system $\{v\}$ and original coordinate system $\{\mathrm{F}\}$ conversion

In coordinate system, assume that 0 coordinate pixel is (A, B), use n to represent pixel length, and then now field position and camera relative position have inseparable connections, and then it can solve $\{v\}$ one point coordinate form is (x_v, y_v) , and we can use co-ordinate conversion form to solve {F} inside corresponding one point (x, y), and then it has:

$$\begin{pmatrix} 1 \\ x \\ y \end{pmatrix} = \begin{pmatrix} 0 & 0 & 1 \\ N & 0 & -aN \\ 0 & N & -bN \end{pmatrix} \begin{pmatrix} 1 \\ x_V \\ y_v \end{pmatrix} \quad (1)$$

According to rightwards offending competition field to make corresponding conversion, then soccer robot posture and position coordinate form can be expressed as $[xv', yv', \theta]^T$ and the point is inside $\{v\}$, assume wp represents site high pixel and Lp represents site long pixel, and then vision handling coordinate form is:

$$\begin{pmatrix} x_V \\ y_V \\ \theta \end{pmatrix} = \begin{pmatrix} Lp - x_V' \\ Wp - y_V' \\ \pi + \theta \end{pmatrix} \quad (2)$$

Above matrix after calculating one cycle, only need to return to {F} transformation homogeneous conversion.

(2)Regarding {F} basic system and {R} soccer robot coordinate system transformation

In coordinate system OXY , assume soccer robot posture is p coordinate as $[a, b, \theta]^T$, then corresponding $O'X'Y'$ one point (x', y') , and corresponding ho-

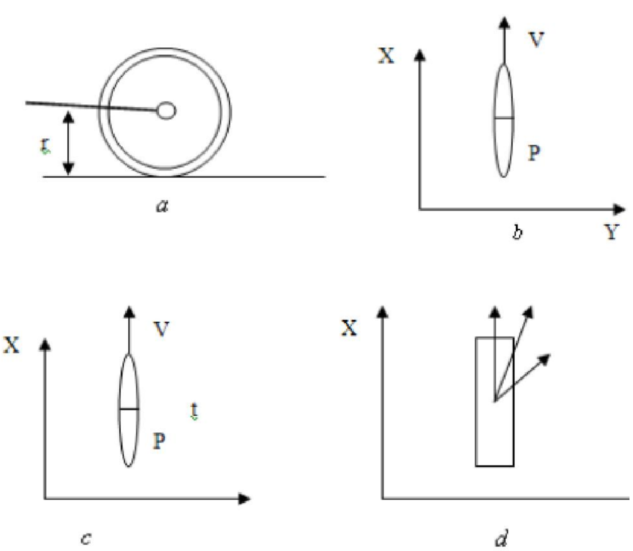

Figure 2 : Schematic wheel movement

mogeneous coordinate form is $(x', y' 1)$, after rotation transformation R and translation transformation T, it changes into (x, y), then corresponding homogeneous coordinate form is (x, y, 1), then R, T matrix can be expressed as:

$$T = \begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & a \\ 0 & 1 & b \end{pmatrix} \quad R = \begin{pmatrix} 0 & 0 & 1 \\ \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \end{pmatrix}$$

Then

$$A = T \cdot R = \begin{bmatrix} 0 & 0 & 1 \\ \cos\theta & -\sin\theta & a \\ \sin\theta & \cos\theta & b \end{bmatrix} \quad \textbf{(3)}$$

Above formula is two coordinates connection required transformational matrix form.

Soccer robot wheel movement mechanical model

Fix wheels on the immotile direction mechanism, as following Figure 2 show:

By above Figure 2, we can get figure's p point speed formula, in formula E_x represents unit vector in x axis, then corresponding formula is:

$$V = (r \times \omega) E_x \quad \textbf{(4)}$$

Assume in above Figure 2 figure c eccentricity is d, in formula, E_y refers to unit vector in y axis, and vector rotates around eccentric shaft is t, then corresponding speed is:

$$V = (r \times \omega) E_x + (d \times t) E_y \quad \textbf{(5)}$$

According to above, it can deduce d figure corresponding speed, and rolling unit vector in formula is expressed by E_y, then speed formula is:

$$V = (r \times \omega) E_x + UE_s \quad \textbf{(6)}$$

Use above wheel several kinds of forms statements, it can get different movement abilities have different wheels; according to former's description, it can divide wheel into five kinds of forms that: $(1,2)(1,1)(2,1)(2,0)(3,0)$, from which presently most important form is $(2,0)$ system.

SOCCER ROBOT KINEMATIC MODELS

If ground and wheel haven't occurred slide phenomena at all, then its movement form is rolling, its equation:

$$V = (r \times \omega) E_x \quad \textbf{(7)}$$

Above formula describes soccer robot movement forms, assume that wheel hasn't occurred sliding in side direction, then the system suffered constraints is:

$$x \sin\theta - y \cos\theta = 0 \quad \textbf{(8)}$$

If ground and robot contacted relative speed is 0, ϕ_R, ϕ_L respectively represent right wheel and left wheel angular speeds, and r represents wheel's radius, L represents left and right half wheels' distance, and then corresponding wheel movement equations are :

$$x \cos\theta + y \sin\theta + L\theta = r\phi_R \quad \textbf{(9)}$$

$$x \cos\theta + y \sin\theta - L\theta = r\phi_L \quad \textbf{(10)}$$

We let $W = [v_L, v_R]^T$ to be soccer robot right direction and left direction wheel speed matrix forms, and ω, v_c represents mass center point angular speed and linear speed, so we can know speed vector equation is ;

$$U = \begin{bmatrix} v_c \\ \omega \end{bmatrix} = \begin{bmatrix} 1/2 & 1/2 \\ -1/2 & 1/2L \end{bmatrix} \begin{bmatrix} v_L \\ v_R \end{bmatrix} \quad \textbf{(11)}$$

Analyze from the perspective of controlling and combine with previous obtained speed formula, we can get soccer robot kinematic equation form is:

$$P = \begin{bmatrix} \theta \\ x_c \\ y_c \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ \cos\theta & 0 \\ \sin\theta & 0 \end{bmatrix} \begin{bmatrix} v_c \\ \omega \end{bmatrix} \quad \textbf{(12)}$$

And by speed vector formula, we can get soccer robot movement trajectory radius is:

$$\rho = \frac{\mathbf{L(v_R + v_L)}}{\mathbf{v_R - v_L}} \quad \textbf{(13)}$$

By wheel speed and soccer robot movement trajectory the two mutual relations, we can get:

① If soccer robot makes circular motion around instant center, then $v_L \neq v_R$.

② If soccer robot rotates with circle center, then $v_L = -v_R$.

③ If curvature radius is infinitely great, and is linear form, then $v_L = v_R$

Soccer robot dynamics correlation research

By combining robot virtual displacement with Lagrange theorem, we can deduce soccer robot dynamics correlation equation, from which Lagrange equation system generalized external force is using τ to express, and generalized coordinate form is using q to express, potential energy is using p to express, kinetic energy is using k to express, then the equation is:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial q}\right) - \frac{\partial L}{\partial q} = \tau \quad (14)$$

$$L = K - P \quad (15)$$

Then we can carry out mobile robot dynamics aspect deduction by above formula.

At first, define $q = [x, y, \theta, \phi_R, \phi_L]^T$ to represent generalized coordinate form, then we can express kinematics model formula as :

$$A(q) = \begin{bmatrix} -\sin\theta & \cos\theta & 0 & 0 & 0 \\ \cos\theta & \sin\theta & L & -r & 0 \\ \cos\theta & \sin\theta & -L & 0 & -r \end{bmatrix} \quad (16)$$

Among them, $A(q)$ is constraint matrix with full rank, we introduce correlation factors, and let, I_{ZB} to be Z_c rotational inertia, then soccer rotational inertia around Z_c axis is $I_Z = I_{ZB} + 2w_c L^2$, robot wheel mass and car body mass are using m_w and m_B to express,

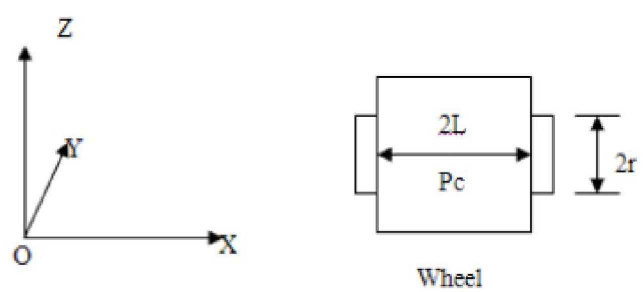

Figure 3 : Geometry and coordinate the definition of mobile robots

then it can get:

$$\mathbf{w} = \mathbf{w_B} + 2\mathbf{w_c} \quad (17)$$

So it can get kinematic constraint formula:

$$\begin{cases} I_y\phi_R = u_1 - r\lambda_1 \\ I_y\phi_R = u_1 - r\lambda_1 \\ I_Z = L\lambda_1 - L\lambda_2 \\ my = \sin\alpha\lambda_1 + \sin\alpha\lambda_2 + \cos\alpha\lambda_3 \\ mx = \cos\alpha\lambda_1 + \cos\lambda_2 - \sin\alpha\lambda_3 \end{cases} \quad (19)$$

By above matrix, we combine with soccer robot set structure and coordinate system and can get following Figure 3:

We can express above formula as matrix form, that:

$$M(q) = \begin{bmatrix} m & 0 & 0 & 0 & 0 \\ 0 & m & 0 & 0 & 0 \\ 0 & 0 & I_z & 0 & 0 \\ 0 & 0 & 0 & I_y & 0 \\ 0 & 0 & 0 & 0 & I_y \end{bmatrix},$$

$$B(q) = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}, \quad u = \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}, \quad \lambda = \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{bmatrix}$$

$c(q, \ddot{q}) = 0$, $g(q) = 0$

By above model, we can accordingly carry out soccer robot path tracking problems controlling.

SOCCER ROBOT MOVING TARGET PATH PLANNING PROBLEMS' RESEARCH MODEL

In order to let soccer robot and soccer integrate in shortest time, we need to consider to move target soccer robot path from target moving problems as following Figure 4 show:

In above coordinate system, we can see that ball takes accelerated speed as 0 movement from starting point p_0 (x_0, y_0) with straight line $AX + BY + C = 0$, so soccer robot firstly arrives at P_0P_d used time is t_1, after that tracks target following the point used time is t_2, the two common used time can be:

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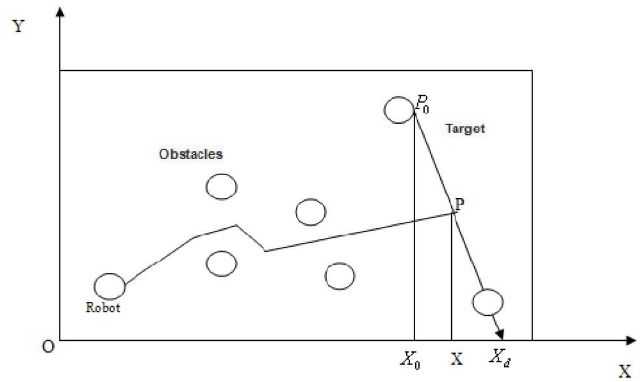

Figure 4 : Planning for mobile robot targets

$$t = t_1 + t_2 \quad (20)$$

The way is solving optimal path process form, in order to simplify the process, assume speed target V_g and soccer robot has great disparities, so that it can let target catch up with target from p_0 to p_d movement process, so to any point $p(x,y)$, by above algorithm, it can arrive at optimal path R, now is $t_1(x)$, but if target is not in the point, then soccer robot needs to continue to go ahead towards the target, and then it can let $t_1(x)$ moment, distance between the two is $\Delta d(x)$, that:

$$\Delta d(X) = \sqrt{(X_0 + V_{gt}t_1(X) - X)^2 + (Y_0 + V_{gt}t_1(X) - Y)^2} \quad (21)$$

And let required time to be t_g, relative to target p, then time is:

$$t_g = \frac{\sqrt{(X - X_0)^2 + (Y - Y_0)^2}}{V_g} \quad (22)$$

So corresponding soccer robot arrives at target point required time is $\Delta t_2(x)$, then it has:

$$\Delta t_2(X) = \begin{cases} \dfrac{\Delta d(X)}{V - V_g} \\ \dfrac{\Delta d(X)}{V + V_g} \end{cases} \quad (23)$$

The two meet time is:

$$t(X) = t_1(X) + \Delta t_2(X) \quad (24)$$

For above paper mentioned optimal path problems' validity problems, we adopt analogue simulation form to test, data is as TABLE 1, its result is as TABLE 2:

By handling, corresponding path planning result is as following Figure 5 show:

From above result, we can see that the model is feasible, so the model will provide important evidence for soccer robot tracking target correlation problems.

TABLE 1: Initial parameter

Object type	Current position	Speed	Safety radius	Movement trajectory
Target	(80,100)	20 cm/s	0 cm	Y=-X+180
Barrier1	(60,80)	0	6 cm	Static
Barrier 4	(50,50)	0	6cm	Vertical and downward
Barrier 2	(100,70)	30 cm/s	6 cm	Static
Robot	(20,15)	50cm/s	6 cm	Intercession
Barrier 3	(40,30)	30 cm/s	6 cm	Horizontal and rightward

TABLE 2 : Simulation parameter

Genetic manipulation order	Group size	Crossover probability	Mutation robability
First time simulation operation	40	0.8	0.1
Second time simulation operation	30	0.8	0.01

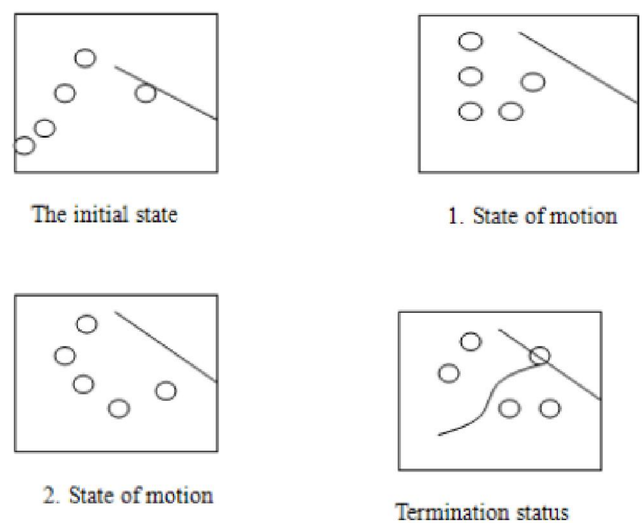

Figure 5 : Path planning simulation results

CONCLUSIONS

The paper solves soccer robot moving mechanism analysis by introducing mechanical model and dynamics correlation equation, and describes as well as designs soccer robot and target optimal path mobile problems, so that it builds foundation for soccer robot movement designing development. In addition, it also verifies soccer robot and target path optimal problems mentioned in the paper by applying analogue simulation forms, so it proves the method has stability, feasibility and other advantages, it will play a navigation role in soccer robot intelligent targets tracking.

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