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Robot football goalkeeper speed control research based on BP neural network algorithm

Hongjun Yang

Shenyang Sport University, Shenyang, China

ABSTRACT

Design and realization of Robot football match system is innovative point and difficulty in artificial intelligence field, the system design including artificial intelligence, digital communication, robotics and sensor so on multiple fields leading edge research, the system realization is a standard high technology experiment platform. This paper takes RoboCup middle-size league robot match system's goalkeeper speed features as research objects to make more scientific, accurate control in goalkeeper speed through reasonable model and algorithm. In this paper, first make analysis of goalkeeper sports object and speed control purpose in robot football match system, make research on world coordinate system and standard coordinate system features, and then carry out stage linear analysis of robot goalkeeper speed state switching , finally build BP neural network non-physical no linear model on the basis of speed theory analysis, get evident better than geometric calculation speed control, provide model base and theoretical evidence for perfecting and making accurate robot football match system.

Key words: World coordinate system, standard coordinate system, BP neural network algorithm, speed control

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INTRODUCTION

At present ,Robot football match with large international influence and scale has mainly two series, they are RoboCup and Federation of International Robot Soccer Association, short for FIRA, from which RoboCup final object is establish fully autonomous personification robot football team in 2050 that can play a real sense of football match with human. Based on above backgrounds, it can be learnt that robot football match system has not yet achieved fully intelligent in a real sense, its final object realization needs efforts from whole world scholars and relative stuff. In every football match, goalkeeper is indispensable, merits of his techniques direct influence on competition results. This paper takes robot goalkeeper as research object; explore its speed control method and optimization method so as to make contribution to final object of robot football match system.

Regarding robot goalkeeper research, lots of scholars have made successive efforts on it, and their research results have been brought in the application of system, provide theoretical evidence to such field development, from which: Indiveri, G. Introduced a goalkeeper control algorithm based on non-linear state reflection, main object of the algorithm is how goalkeeper make effective follow and intercept according to football [1, 2]; Huang Yan-Wen etc. Put forward a robot sports control algorithm based on PID, achieve control purposed through adjust and optimize PID parameters according to different sports requirements [2, 3]; Menegnatti, E.etc. Put forward goalkeeper compound motion control design, as goalkeeper barrier control, arc sports control, door intercept motion design and so on, make detailed introduction of goalkeeper motion switching according to different match conditions [4, 5].

This paper based on previous research, make analysis of robot football goalkeeper speed features so as to establish scientific speed control model and control algorithm through analysis results, and provide theoretical foundation to robot football match rational development.

ROBOT GOALKEEPER KINEMATIC MODEL ESTABLISHMENT AND ANALYSIS

In football process, liability of goalkeeper except for correct stance, timely correctly moving to target point also is required so as to catch or intercept to-be shoot football, similarly in robot football design process, it has the same requirement to goalkeeper. In order to make goalkeeper timely moving to target point, it is necessary to make its speed control. Too big or too small of goalkeeper sports speed would do harm to defense, therefore make different speed control to goalkeeper under different situations can improve its defense success rate.

This chapter makes research on goalkeeper speed stage and kinematics model to provide theoretical foundation for robot football control through reasonable model designing of more reliable accurate algorithm.

Establishment of Robot goalkeeper kinematics coordinate system

In robot football match process, its system has two coordinate systems, one is world coordinate system, the other is robot standard coordinate system, world coordinate system define ground center as origins coordinate, direction that point to opponent goal center is X axis positive direction, define X axis rotates 90 degree counterclockwise direction as Y axis positive direction, size of match field is 18m*12m,its unit scale is millimeter, given own party goal center location coordinate as （-9000,0），opponent goal center coordinate location as （9000,0）, the field location status in world coordinate as Figure 1 shows.

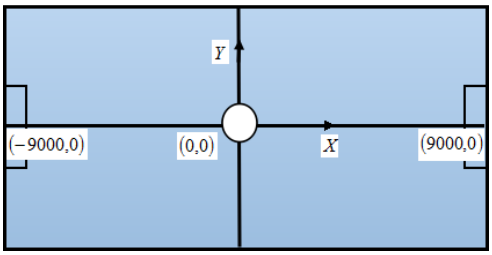

Figure 1: schematic diagram of robot football match spot location distribution in world coordinate system

Robot standard coordinate system is also called relative coordinate system, which takes robot all-around visual system center as coordinate system origins, with robot front side as X axis positive direction, its Y axis positive direction is the direction that X axis rotate counterclockwise at 90 degree, its standard coordinate system as Figure 2 shows.

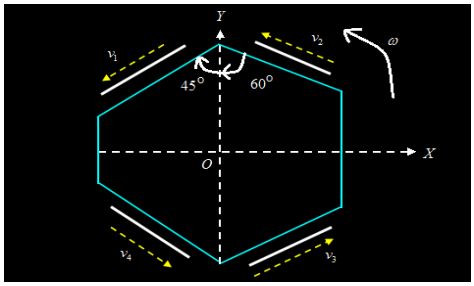

Figure 2: Robot goalkeeper standard coordinate system schematic diagram

Standard coordinate system is robot gets its own location information confronts to feature districts in field through self-positioning, correct and defines robot world coordinate system in the field through corresponding switching and combines sensors information fusion techniques.

Robot goalkeeper speed breakdown

In the four wheels from robot goalkeeper as Figure 2 shows, the 2nd wheel and 3rd wheel are in the front, while the 1st and 4th wheel are in the back, therefore let robot translational speed represent as V, speed component in X,Y axis positive direction are respectively V_x,V_y, distance between drive center and robot center $R=22.5\text{cm}$, ω represents robot self rotation angular speed，robot goalkeeper four wheels speed can be got as formula (1) shows.

$$\begin{cases} v_1 = \omega R - V_x \cos 45^O - V_y \sin 45^O \\ v_2 = \omega R - V_x \sin 60^O + V_y \cos 60^O \\ v_3 = \omega R + V_x \sin 60^O + V_y \cos 60^O \\ v_4 = \omega R + V_x \cos 45^O - V_y \sin 45^O \end{cases} \quad (1)$$

Bring data $R = 0.225, \cos 45^O = \frac{\sqrt{2}}{2}, \sin 45^O = \frac{\sqrt{2}}{2}, \cos 60^O = \frac{1}{2}, \sin 60^O = \frac{\sqrt{3}}{2}$ into formula（1）can get formula（2）:

$$\begin{pmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \end{pmatrix} = \begin{bmatrix} -\frac{\sqrt{2}}{2} & -\frac{\sqrt{2}}{2} & 0.255 \\ -\frac{\sqrt{3}}{2} & \frac{1}{2} & 0.255 \\ \frac{\sqrt{3}}{2} & \frac{1}{2} & 0.255 \\ \frac{\sqrt{2}}{2} & -\frac{\sqrt{2}}{2} & 0.255 \end{bmatrix} \begin{bmatrix} V_x \\ V_y \\ \omega \end{bmatrix} \quad (2)$$

Robot goalkeeper sport speed stage analysis

Goalkeeper sports speed should be defined with field information and goalkeeper own nature, if goalkeeper move too slow, it would cause fumble without arriving special location, while if he moves too quick, it would lead to opponent robot adjust attack and make failed in defense, therefore it is very important to reasonable adjust goalkeeper sports speed.

In order to let goalkeeper timely arrives at target point, his sports path should choose the shortest one, control goalkeeper speed according to distances between goalkeeper and target point, when distance is far ,move to target point at maximum speed, after distance becomes near to some extent should control robot and start decreasing speed, from which speed decreasing process is by evident of distance deviation, control accelerated speed into smaller and smaller till stop, Figure 3 shows the contrast images of variable accelerated speed and constant accelerated speed decrease into target point's speed time.

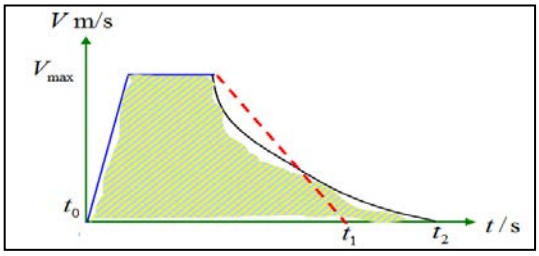

Figure 3: Speed time contrast images of variable accelerated speed decreasing and constant accelerated speed decreasing to target point

In Figure 3, black real cure expresses variable accelerated speed's decreasing process; red imaginary straight line expresses constant accelerated speed's decreasing process. From images, it can be known that constant accelerated speed decreasing spends more time than variable accelerated speed decreasing in the same displacement.

Current status is hard to allow precise robot dynamics model, therefore it is hard to fix accelerated speed decreasing .Stage linear control of sports speed according to distance between robot and target point, its speed changes image as Figure 4 shows.

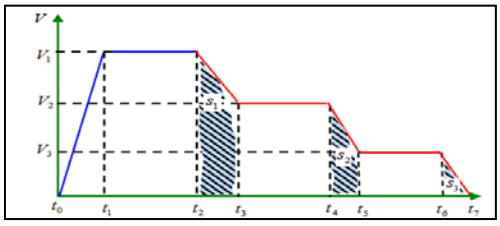

Figure 4: Stage linear sports speed image

In Figure 4, goalkeeper moves with at top speed v_1 in the time frame of $t_1 \sim t_2$, it need to make goalkeeper try to arrive at fastest speed., goalkeeper moves at middle speed v_2 in the time frame of $t_3 \sim t_4$, goalkeeper moves at low speed in the time frame of $t_5 \sim t_6$, goalkeeper is in the accelerates speed starting stage in the time frame of $t_0 \sim t_1$, while all in the constant deceleration stage in the time frame of $t_2 \sim t_3$, $t_4 \sim t_5$, $t_6 \sim t_7$.

According to Figure 4 robot speed changes image, it can be known goalkeeper complete speed changes from starting to ending as Figure 5 shows.

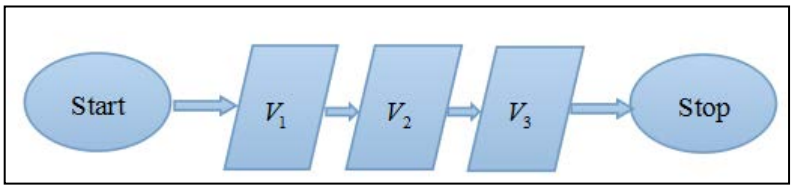

Figure 5: Robot goalkeeper speed status switching schematic diagram

Robot goalkeeper speed status as Figure 5 shows is not required fully experienced in operation. Normally proper status switching be chosen according to distance between goalkeeper and target point location, which requires time that goalkeeper arrives at target point should be slightly small or equal to that ball arrives at target point, goalkeeper defense can be more effective only in this way.

ROBOT GOALKEEPER SPEED CONTROL ALGORITHM AND REALIZATION

In the previous chapter, stage analysis of goalkeeper speed has been made, it has been divided into start stage, high speed stage, middle speed stage, low speed stage and decelerated stage while in actual match, it is proper to make more stage change for goalkeeper speed so as to let them quick and correct save, normally simply into start stage, high speed stage and decelerated stage, from which high speed stage usually is to make constant speed movements. Therefore, goalkeeper should go through at least 3 linear stages moving from stance point to target point, and the core of speed control algorithm also is numerical control of such 3 stages goalkeeper operation time and accelerated speed to fulfill goalkeeper successful defense speed control.

In order to avoid multiple interference factors caused by complex of match environment, this chapter puts forward BP neural network speed control algorithm to provide more reasonable strategies to robot goalkeeper speed control.

BP neural network speed control algorithm analysis

The control purpose of BP neural network algorithm is to make goalkeeper earlier arrive at target point than ball or arrive in the same time with ball, and stop immediately after arriving at target point, based on above control objective, similarly can divide the process that goalkeeper from stance point to target point into 3 stages, are respectively accelerated stage, constant speed stage and decelerated stage, as Figure 6 shows the robot goalkeeper three step planning image.

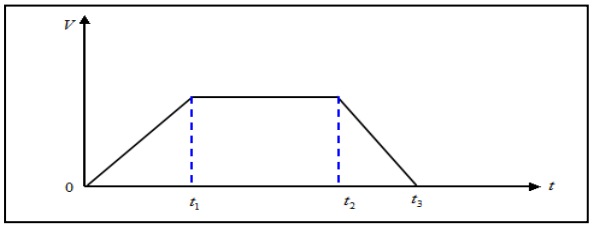

Figure 6: Robot goalkeeper speed control objective three step planning image

When opposite side guard shoots, normally ball speed is quite large, therefore goalkeeper should also handle it with larger speed so as to success defense, so goalkeeper is required not only accelerate with maximum accelerated speed in accelerated stage, but also decrease speed into zero when nearly close to target point in decelerated stage so that goalkeeper also should decelerate speed with maximum accelerates speed in decelerated stage. The maximum accelerated speed is defined, so it is easy to confirm three stages goalkeeper movements each data only with information of ball speed in constant speed stage.

In order to make goalkeeper timely arrive at target point and decelerate into zero, goalkeeper not always moves at maximum speed at constant speed stage, therefore the constant speed is unknown that need to make solution, while also due to known numbers is not enough to make direct solution, this paper applies BP neural network algorithm to solute constant stage's speed and running time.

To define constant speed stage goalkeeper speed v_{goalie} and sports time t_{goalie}, related data to the two should be extracted, it's obvious that goalkeeper constant speed sports time as well as speeds are mainly determined by distance between ball and target points d_{ball},ball motion speed v_{ball} and ball motion direction θ_{ball} as well as distance between goalkeeper and target point d_{goalie} such 4 factors, the above 6 factors are not in linear relations, therefore utilize neural network algorithm to train samples value, non-linear relations neural network model among v_{goalie}、t_{goalie}和d_{ball}、v_{ball}、θ_{ball}、d_{goalie} can be got, build a third of neural network model with four inputs and two outputs as Figure 7 shows.

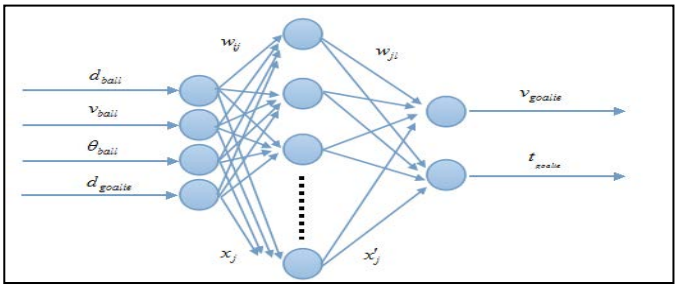

Figure 7: Robot goalkeeper constant speed solution neural network structural model schematic diagram

BP algorithm learning process divides into two stages, first is competing transfer process, the second is reverse transfer process. In Figure 6, d_{ball}、v_{ball}、θ_{ball}、d_{goalie} is the input of network, v_{goalie}、t_{goalie} is the output of network, w_{ij} represents output from input layer to hidden layer, w_{jl} represents weight from hidden layer to output layer, and $i=1,2,3,4$, $j=1,2,\cdots,9$, $l=1,2$ network output as formula (3) shows.

$$\begin{cases} v_{goalie}=\sum_{j=1}^{9} w_{j1}x'_j \\ t_{goalie}=\sum_{j=1}^{9} w_{j2}x'_j \end{cases} \quad (3)$$

In formula (3), x_j, x'_j as formula (4) shows.

$$\begin{cases} x_j=\left(d_{ball}+v+\theta+d_{goalie}\right)\sum_{i=1}^{4} w_{ij} \\ x'_j=\left(1+e^{-x_j}\right)^{-1} \end{cases} \quad (4)$$

If given v^0_{goalie} as desirable output of goalkeeper speed，t^0_{goalie} as desirable output of goalkeeper motion time ，then network imminent error performance index function as formula(5) shows.

$$E(k)=\frac{1}{2}\left[\left(v_{goalie}-v^0_{goalie}\right)^2+\left(t_{goalie}-t^0_{goalie}\right)^2\right] \quad (5)$$

Since accelerate and decelerate at maximum accelerate speed, accelerated stage motion time t_1 can be got, obviously decelerated stage has the same motion time as that in accelerated stage. To sum up, players speed control process from stance point to target point is achieved.

Algorithm implementation environment, setting and results analysis

In training BP neural network, lots of save scenes constructed in middle size leaguer match platform, write down goalkeeper save successes data, totally 4000 groups successful pass samples data recorded to BP neural network training; before training, normalization handling of samples data should be done, from which initial value of weight w_{ij} and w_{jl} adopt random number between $[-1,+1]$,learning parameters $\eta = 0.50, \alpha = 0.05$, through nearly 1 hour learning, network tends to convergence state, network imminent error is approximately 0.001, its convergence process as Figure 8 shows.

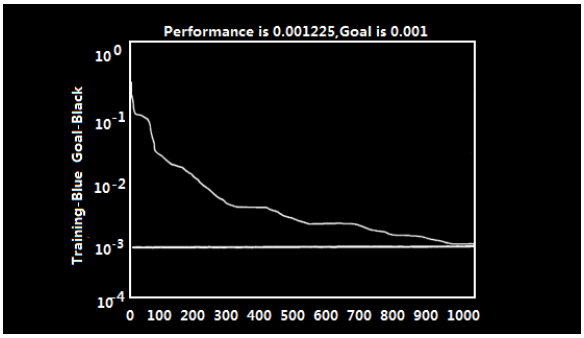

Figure 8: BP neural network samples training convergence process data image

Bring well trained neural network into actual match, which has a remarkable advantage over traditional geometric calculation's speed control algorithm by comparison, contrast condition of two speed control algorithm effect as Table 1 shows.

Table1: Neural network speed control—geometric calculation speed control effects comparison

control algorithm type	own goal shooting times	success defense times	defense success rate
geometric calculation speed control	60	28	46.7%
BP neural network speed control	60	41	68.3%

From Table 1 data, it can be known that improved speed control algorithm based on BP neural network obviously has an advantage over traditional speed control algorithm based on geometric calculation. BP neural network algorithm implementation not need precise physical model, good results can be got once arriving at quick convergence speed and enough small imminent error in network training, and disadvantages of neural network algorithm after the hypothesis also occurred. In BP neural network approach algorithm, network initial weigh is hard to confirm, if its value not chosen properly, approach precise would be reduced and even cause more network divergent; Robot football match has high real time performance, if chosen neural network too complicated , hid den layer point too many, calculation would be increased and reduce real time performance.

CONCLUSION

This paper analyzed goalkeeper duty as well as football goalkeeper required control objects in actual football match ,introduced robot football match systems' two large coordinate system as well as robot goalkeeper speed breakdown model and speed state stage features, detailed introduced BP neural network algorithm theory and such algorithm implementation process in robot football goalkeeper speed control; make comparison with geometric calculation speed control effects, stated speed control advantages based on BP neural network algorithm, and deeply analysis BP neural network algorithm advantages and disadvantages.

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