A competitive strategy of ball snatching for soccer robots

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Abstract. During the movement of the soccer robot, the soccer robot is in a complex environment of real-time confrontation, which requires the robot to have a higher ability to cope with the real-time movement process. It is necessary to make reasonable countermeasures for each critical moment, such as the process of multi-robot grabbing. Many strategy studies only focus on the path planning of the single-robot ball control process, without considering the process of multi-robot competition, leading to the lack of some key steps in the entire motion process of the soccer robot, loss of integrity, and neglect of real-time confrontation. It is proposed to use WTA (Winner Take All) competition model to effectively solve the multi-robot competition problem. The model is described by an ordinary differential equation. This paper verifies the correctness of the theory through simulation experiments, and also verifies the scientificity and practicality of the proposed theory. Laid the foundation for future practice in other scientific fields.

1. Introduction
The research of soccer robot[1] system involves a very wide range of fields[2], including mechatronics, robotics, Sensor information fusion, intelligent control, communication, computer vision, Computer graphics, artificial intelligence[3], and so on. It has attracted the active participation of the vast number of scientific researchers and engineers from all over the world.

The soccer robot is a multi-agent, which itself is a collection of multiple technologies, and has high research value for multiple disciplines [4], which is for the individual itself. However, they are the same replica, with many similar "activities", and they can form a team. It is not only limited to the research of the individual intelligence modules, but can also rise to the research between the entire team. For example: research on complex relationships such as competition and collaboration. Football robots can use advanced technology such as artificial intelligence to simulate the actual game mode of athletes and perform a very exciting robot football game. The robot soccer game involves research methods in multiple fields. Through the robot game, it can promote the exchange of ideas and introduce new technologies. Relevant experts and scholars also take the control of soccer robots as the research object and conduct in-depth research on it. More mature theory and application.

Football robots will be affected by obstacles and the randomness of the football situation during the movement. Intelligent control design is required for them, and their energy consumption must also be considered. In order to improve the intelligent control ability of soccer robots, the study of optimal control methods of soccer robots is of great significance in the design of soccer robots and game optimization.

Competition exists widely in nature and society [5]. Among different types of competition, "winner takes all" refers to the phenomenon of individuals competing with each other in the group [6]. Only
the individual with the highest input remains active, and the rest are inhibited. Examples of this type of competition include the dominant growth of the central backbone, the contrast gain in the visual system through the winner-takes-all competition between neurons [7], cortical decision-making competition [8], and competition-based multi-robot coordinated control [9] etc.

Although many of the phenomena illustrated above show the same winner-takes-all game, they may have different basic principles responsible for dynamic evolution. In addition to the characteristics of distributed storage and high-speed parallel processing, neural networks can be easily implemented by hardware, and have been widely used in various fields, including competition [10-12]. For example, the N-type Lotka-Volterra model introduced in [13] is interactively inserted into the Fitzhugh-Nagumo model. This paper uses a WTA competition model described by ordinary differential equations to solve the soccer robot competition problem.

2. Propose the problem
In the soccer robot system, its operating environment is partly known, partly unknown, contains static and dynamic obstacles, and is a competitive dynamic environment that changes all the time. Both sides dispatched 11 football robots to play football matches on the prescribed field. All competition environments are conducted in an ideal state, without considering the influence of excessive man-made and other natural forces. When the game started, both sides were still in their respective fields. Waiting for the transmission of the game instructions, the players from both sides went to grab the football. When one team successfully grabs the football, it controls the football to move towards the opponent's goal. In the process, they will encounter obstacles from the opposing player, successfully surmount the obstacle, reach the opposing goal, and win the game. Otherwise, the ball will reach the opponent's player and repeat the above process until one side wins and the game ends.

This article studies the sports competition of multiple soccer robots. The game is usually a dynamic process. In a dynamic system, if each component is disorderly and does not follow certain rules in an orderly manner, then some corresponding problems will arise. For the two teams of soccer robots that are competing, in the process of grabbing the football, you can formulate rules to allow only the robot with the greatest football advantage to grab the ball, and the other robots can stay on standby. This saves the energy of the entire system.

3. Control scheme based on winner-takes-all
3.1. Multi-robot competition
The soccer robot game is a competitive sport involving multiple people. During the game, the robot is in constant motion, changing the state of motion from time to time, which is a process of continuous change in a continuous time. In this way, the relationship between time and motion state is not simply a linear relationship, and there is no necessary connection between time and motion state, which is a non-linear relationship. After all, robots cannot have developed brains like humans, and can control their behaviors freely and smartly. If you continue to follow the originally set procedure, it is likely to get twice the result with half the effort. Not only hinder his teammates, but also help each other invisibly. Therefore, a relatively reliable strategy is needed to control the robot's behavior.

The traditional method requires all players to chase the football, and in the end only one robot grabs the football. In this way, the energy of other robots that have not grabbed the football is wasted. According to the above method, only the nearest robot is allowed to chase the football, saving a lot of unnecessary energy expenditure.

In this article, WTA (winner-take-all) auxiliary competition model will be used to describe this non-linear competition relationship in continuous time. In football, the distance from each robot is different, and in order to control the football more conveniently and quickly, it is necessary to find a player with the most advantage (the closest distance) from the football to control the football [21]. Moreover, football is a moving object, which can be regarded as a dynamic system, and the players...
with the most advantage from football are changing all the time. This requires finding the most advantageous player to control, so as to achieve more efficiency.

3.2. WTA assisted competition model

The following will introduce the establishment of the WTA competition model and the basic analysis of the model itself.

There are n robots in a group, then its $i$th robot has the following dynamic process:

$$\dot{v}_i = \xi \left( \frac{1}{d_i} - \|v\|^2 \right) v_i$$  \hspace{1cm} (1)

Where $v_i \in \mathbb{R}$ is the state vector of speed of the $i$th robot, $v_i \neq v_j$ for $i \neq j$, $d_i \in \mathbb{R}$ represents the distance between the position of the robot and the football, $d_i \neq d_j$ for $i \neq j$. $\|v\| = \sqrt{v_1^2 + v_2^2 + \ldots + v_n^2}$ represents the Euclidean norm of the state vector of $v = [v_1, v_2, \ldots, v_n]^T$, $\xi$ is a constant proportional factor.

Let $\frac{1}{d_i} = s_i$, by superimposing the states of all the soccer robots, the dynamic equation can be written in the following compact form:

$$\dot{v} = \xi \left( s \circ v - \|v\|^2 v \right)$$  \hspace{1cm} (2)

Where $v = [v_1, v_2, \ldots, v_n]^T$, $s = [s_1, s_2, \ldots, s_n]^T$, the operator “$\circ$” represents component multiplication, $s \circ v = [s_1 v_1, s_2 v_2, \ldots, s_n v_n]$.

3.3. Model analysis

This model can intuitively explain the results of positive feedback and negative feedback. Please note that the term $\xi s_i v_i$ in equation (1) provides positive feedback of the state variable $v_i$, the term $\xi \|v\|^2 v$ provide negative feedback. For the $i$th robot, if $s_i = \|v\|^2$, $v_i$ will keep this value. If $s_i < \|v\|^2$, then the positive feedback is less than the negative feedback, and the state value decays to zero. On the contrary, if $s_i > \|v\|^2$, the positive feedback is greater than the negative feedback, and the state value tends to increase as much as possible until the increase of $\|v\|^2$ exceeds $s_i$. Especially for the winner, say the $k$th robot, $s_k > s_i$ holds for all $i \neq k$. In this case, all robots have negative feedbacks and keep reducing in values until $\|v\|^2$ reduces to the value of $s_k$ when $s_k < \|v\|^2$. Otherwise when $s_k$ is slightly greater than $\|v\|^2$ (by slightly greater we mean $s_k > \|v\|^2$ with $l$ denoting the robot with the second largest state value), only the winner has a positive feedback and has an increase in its state value while all the other robots have negative feedbacks and keep reducing until $\|v\|^2$ equals $s_k$. Under this selective positive-negative feedback mechanism, the winner finally stays active at the value $s_k = \|v\|^2$ while the losers are deactivated to zero.
4. Numerical Simulation Verification

4.1. The winner-takes-all experiment

In this section, simulation experiments will be used to illustrate the winner-take-all phenomenon generated by robot dynamics. Consider two aspects, one is static competition, that is, the input value $s$ is constant; the other is dynamic competition, that is, the input $s$ changes with time.

For the static competition problem, that is, at the beginning of the game, both sides are in a static state. The input value $s$ does not change with time. In the experiment, there are 11 robots, that is, $n = 11$. The input value $s$ is randomly generated between 0 and 1, and the state value varies between -1 and 1. In the simulation, in order to make the process more convenient and simple, choose $\xi = 1$.

First randomly select 11 values of $s$. $s=\{0.8032, 0.6198, 0.4206, 0.2529, 0.2112, 0.1443, 0.9184, 0.2509, 0.4353, 0.0486, 0.7802\}$, Random initialization $v_0=\{0.9711, -0.9966, -0.6186, -0.6291, 0.1111, 0.2714, 0.1963, 0.8897, -0.0087, -0.6009, -0.7281\}$.

The experimental results are shown in Figure 1:

![Time history of the state variable v](image)

Fig.1 Time history of the state variable $v$

In the above figure, the abscissa represents the iteration time, and the ordinate represents the output value, which represents the state of the robot over time. The lines are smooth curves. The curves of different colors represent different robots, and their states change with time in the same coordinate system. As shown in the figure above, the running result shows that after multiple iterations, the seventh robot (that is, the one with the largest input value) reaches the maximum value, which is closest to 1, and belongs to the winner. Others converge to 0 and belong to the loser. Their activities will be restricted and will not compete with the winner. The experimental results show that the initial value of the input value is the maximum value, and the result calculated by the model introduced above can be the closest to 1, reaching the maximum value. The initial value is the largest, and the reciprocal is the smallest. In the robot soccer game, the distance between the robot and the soccer ball is the closest. The robot closest to the ball will kick the ball first, and the others will be on standby. This will not affect the movement of the ball-controlling robot and make the entire team look orderly. This is in line with the previous expectations, can save the energy of the football robot, and also reduce the damage of the robot itself caused by the collision in the process of grabbing the ball.

4.2. The winner-takes-all experiment

In the next experiment, we analyze the influence of the coefficients $\xi$ of the WTA model on the rate of model convergence. For the dynamic equation (1), $\xi$ respectively take the value $\xi = 2, \xi = 3, \xi = 5, \xi = 10$. The experimental results are shown in Figure 2. According to the results, we can see that when $\xi = 2$, the model converges after 30s; when $\xi = 3$, the model converges after 21s; when
\( \xi = 5 \), the model converges after 12s; when \( \xi = 10 \), the model converges after 6s. From this we can get that the larger the value of \( \xi \), the faster the convergence speed of the model.

5. Conclusion
This article describes the movement process of the soccer robot, which is more complete than the traditional way. The WTA continuous-time non-linear assisted competition model is used to solve the process of multi-robot competition for football. Compared with the traditional method, it can find the robot with the most advantage in the distance football in real time, control the ball first, and save the energy consumption of unnecessary robots. The experimental results also verified the conjecture and made the theory more rigorous. It also provides a basis for the research of more intelligent soccer robot motion process in the future.

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References
[1] Guan Yingzi, Liu Wenxu, Yan Ning, et al. Research on Cooperative Motion Planning of Space Multi-robots[J]. Chinese Journal of Mechanical Engineering, 2019, 55(12): 37-43(in Chinese).
[2] Lu Huimin, Zhang Hui, Yang Shaowu, et al. A robust self-localization method for soccer robot based on omnidirectional vision[J]. Robot, 2010, 32(4):553-559+567(in Chinese).
[3] Zeng H Y, Ding Jieyu. Application of artificial intelligence technology in soccer robots[J]. Science & Technology Innovation Herald, 2018, 15(28): 108+110(in Chinese).

[4] Liang Xiaodan, Lin Na, Chen Hanning. Dynamic path planning of mobile robots based on bacterial foraging behavior[J]. Chinese Journal of Scientific Instrument, 2016, 37(06):1316-1324. (in Chinese)

[5] Li S, Zhang Y, Jin L. Kinematic control of redundant manipulators using neural networks[J]. IEEE transactions on neural networks and learning systems, 2016, 28(10):2243-2254.

[6] Jin L, Zhang Y, Li S, et al. Modified ZNN for time-varying quadratic programming with inherent tolerance to noises and its application to kinematic redundancy resolution of robot manipulators[J]. IEEE Transactions on Industrial Electronics, 2016, 63(11): 6978-6988.

[7] Lee D K, Itti L, Koch C, et al. Attention activates winner-take-all competition among visual filters[J]. Nature neuroscience, 1999, 2(4): 375.

[8] Emilio H, Lopez C, Pigolotti S, Andersen K. Species competition: coexistence, exclusion and clustering[J]. Philosophical Transactions of the Royal Society A Mathematical Physical and Engineering Sciences, 2008, 367(3):3183–3195.

[9] Jin L, Li S. Distributed task allocation of multiple robots: A control perspective[J]. IEEE Transactions on Systems, Man, and Cybernetics: Systems 2017, pp(99):1–9.

[10] Hu X, Wang J. An improved dual neural network for solving a class of quadratic programming problems and its k-winners-take-all application. IEEE Transactions on Neural Networks, 2006,19(12):2022–2031

[11] Jin L, Zhang Y. Discrete-time Zhang neural network for online time-varying nonlinear optimization with application to manipulator motion generation. IEEE Transactions on Neural Networks and Learning Systems, 2015,27(6):1525–1531

[12] Li S, He J, Rafique U, Li Y. Distributed recurrent neural networks for cooperative control of manipulators: A game-theoretic perspective. IEEE Transactions on Neural Networks and Learning Systems, 2017,28(2):415–426

[13] Ramirez-Angulo J, Ducoudray-Acevedo G, Carvajal R, Lopez-Martin A. Low-voltage high-performance voltage-mode and current-mode wta circuits based on flipped voltage followers. IEEE Transactions on Circuits and Systems II: Express Briefs, 2005,52(7):420–423