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Robot soccer match location prediction and the applied research of Kalman filtering algorithm

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ABSTRACT

In a dynamic environment, it is not an easy task to position the soccer robot accurately, this paper studies the problem, to hit the dynamic football, and the robot must first determine the position of the football and him. The results show that the Kalman filter algorithm is an algorithm to predict the location of the football and the other in the shortest possible time, this algorithm has a very wide range of adaptability.

Key words: Kalman filtering algorithm, Robot Soccer, Position prediction, the optimization algorithm

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INTRODUCTION

The robot soccer is more and more advanced with the development of the Times, among which the Navigation system is an indispensable part of robot soccer. As the robot's brain, the Navigation system acts as the role of a commander. However, for the robot soccer, only to determine their own position, the next step of decision making and planning can be carried out [1-5]. Predecessors have made many achievements for the research of robot location [6-9]. For example, Ma Hui et al proposed that the technique can be divided into two types for the research of robot soccer positioning, including absolute and relative positioning of the positioning [10-13]. Both are locating the position of the robot through geometrical relationship, then extracting the calculation system for calculating coordinate input.

This article research is precisely establishes above the foundation which the scholar studies, Kalman filtering algorithm is established, improved and Verified by experiment. Finally, the experimental results that this algorithm plays an important role for robot soccer development and improvement.

THE COMPOSITION OF THE KALMAN FILTERING METHOD OF MODEL

Robot soccer match is an important part in the field of artificial intelligence. During the match, Data acquisition is under a closed system, as shown in Figure 1.

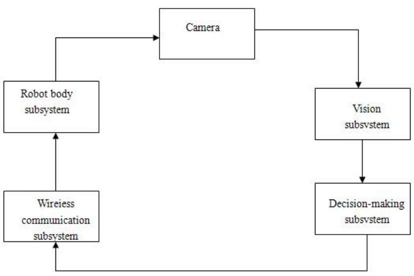

Figure 1: Soccer robot is always in the process of repeat the above, then the game proceed smoothly

The establishment of the Kalman filtering method of the model
In the early, in order to solve the problem of noise generated by the radar, the filtering prediction theory was introduced, but it had flaws, in order to compensate for this drawback, a Kalman filter algorithm was produced.

Assumptions need to be made in order to establish the system of observation and state space model of Kalman filtering algorithm.

The state of the system can not be directly observed;

The whole process of the influence of noise can be ignored

Control inputs affect the state of the system
Under such circumstances, W_p represents systematic procedure incentive noise, U_p represents System control input, X_p and represents System state variables, so we can get stochastic differential equations of this status:

$$X_p = AX_{p-1} + BU_p + W_{p-1} \tag{2.1}$$

V_p Represents noise observation, Z_p represents the observed variables, so we can get a stochastic differential equations of this status:

$$Z_p = CX_p + V_p \tag{2.2}$$

If the two independent quantities V_p, W_p, R represents Measurement noise covariance matrix, Q represents Excitation process noise covariance matrix, there $V_P \sim N(0,\ R)$, $W_P \sim N(0,\ Q)$, State transition matrix of the system is represented by A, Observation matrix is represented by H. Posteriori error estimation and state estimation is represented by $\hat{X}_p$ and $e_p = X_p - \hat{X}_p$, Frontier state estimation and error estimation with $\hat{X}_p^-$ and $e_p^- = X_p - \hat{X}_p$. Therefore, we can conclude that the two corresponding covariance are:

$$P_p = E\left(e_p e_p^T\right) \tag{2.3}$$

$$P_p^- = E\left(e_p^- e_p^{-T}\right) \tag{2.4}$$

The weighted Measuring estimate and Measurements with Priori status then in the linear combination, we can get:

$$\hat{X}_p = \hat{X}_p^- + K\left(\hat{Z}_p - C\hat{X}_p^-\right) \tag{2.5}$$

Among them, the measurement residual formula above is represented by $Z_p - CX_p^-$, it actually reflects the difference between the numerical value and the pre-estimation of measurement between the actual measurement, the solving about Kaman gain p is:

$$K_p = P_p^- C^T \left(CP_p^- C^T + R\right)^{-1} \tag{2.6}$$

Through the analysis above, we get that Kalman filter algorithm is actually a semi-closed loop control of a structure, it is the operation of the system in the form of a feedback process, through above, the posterior circulation of two different estimates of the process and the never-ending cycle of estimates of filtering can be established.
The measurement update equations are:

$$K_p = P_p^- C^T \left(CP_p^- C^T + R\right)^{-1} \tag{2.8}$$

$$\hat{X}_p = \hat{X}_p^- + K\left(\hat{Z}_p - C\hat{X}_p^-\right) \tag{2.9}$$

The formula about the update of time is:

$$P_p^- = AP_{p-1}A^T + Q \tag{2.10}$$

$$\hat{X}_p^- = A\hat{X}_{p-1} + B\hat{U}_{p-1} \tag{2.11}$$

We can describe the principle of this algorithm through a process flow diagram. As shown in Figure 2:

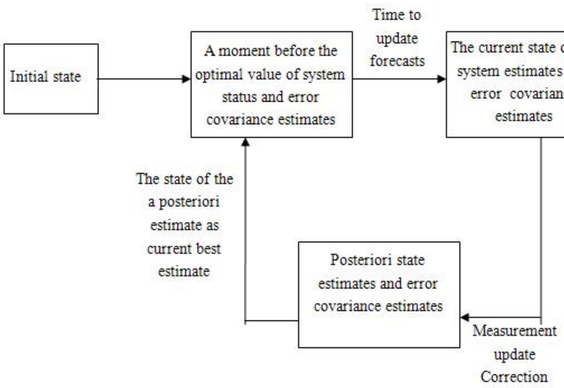

Figure 2:Block diagram of the Kalman filter

As the starting error $P(O)$ and state $X(0)$ is known. We can get an accurate estimate of the system state.

THE EXTENSION OF THE KALMAN FILTER ALGORITHM

Considering the $x_p = f(x_{p-1}, u_{p-1}, w_{p-1})$ is a nonlinear process, Coleman filtering and linear measurements $z_{p-1} = h(x_p, v_p)$ is very similar in the process, Thus, we can get the formula about the update on time prediction:

$$P_p^- = A_p P_{p-1} A_p^T + W_p Q_{p-1} W_p^T \tag{3.1}$$

$$x_p = f(x_{p-1}, u_{p-1}, 0) \tag{3.2}$$

After correction equation, we get the updated formula:

$$P_p = (1 - K_p C) P_p^- \tag{3.3}$$

$$\hat{X}_p = \hat{X}_p^- + K_p\left(\hat{Z}_p - h(\hat{x}_p^-, 0)\right) \tag{3.4}$$

$$K_p = P_p^- C_p^T \left(C_p P_p^- C_p^T + V_p R_p V_p^T\right)^{-1} \tag{3.5}$$

Each p of the above formulas are in the fundamental change for V、C、W、A, if the iteration time is long enough, the incorrectly initial offset values will be offset such that the filter converges to the best state.

In this paper, the function of two linearly combined to replace the original derivative function, this is based on the principle of filter, and the improved process is:

$$X_{p+1} = X_p + h\sum_{m=1}^{v} a_m K_m \tag{3.6}$$

The number of $f()$ is represented in v, while the undetermined factor are expressed in a_m, Then the relation who k_m need to be met is:

$$K_m = f\left(t_p + c_m l, X_p + l\sum_{j=1}^{m-1} b_{mj} K_j\right) \quad (3.7)$$

To improve the accuracy of prediction with the correction method of matrix to replace the observation matrix, the steps are as follows:

$$Z_{p+1} = h(X_{p+1/p}) + C(X_{p+1/p})(X - X_{p+1/p}) \quad (3.8)$$

$$Z_{p+1} = h(X_{p+1/p}) + g(Z_{p+1}, X_{p+1/p})(X - X_{p+1/p}) \quad (3.9)$$

$$P_{P+1/P+1} = \left[1 - K_{p+1} * g(Z_{p+1}, X_{p+1/p})\right] P_{p+1/p} \left[1 - K_{p+1} * g(Z_{p+1}, X_{p+1/p})\right]^T \quad (3.10)$$

On the type of the observation matrix is represented in $g(Z_{p+1}, X_{p+1/p})$, as the correction function matrix is represented in $C_{p+1}(X_{p+1/p})$, by the equation above, we can get that in the next step the observation matrix is much more higher than correction matrix about the forecast accuracy .

THE RESEARCH ABOUT SOCCER ROBOT POSITION PREDICTION MODEL

At first will describe the cameras captured football movement with coordinate, its formula is as follows:

$$X_p = (x, y, v_x, v_y)^T \quad (4.1)$$

So you can get the equations of the motion of football:

$$X_p = MX_{p-1} + acc_p$$
$$= \begin{bmatrix} 1 & 0 & \Delta tN & 0 \\ 0 & 1 & 0 & \Delta tN \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} X_{p-1} + \begin{bmatrix} \frac{1}{2} a_x (\Delta tN)^2 \\ \frac{1}{2} a_x (\Delta tN)^2 \\ a_x (\Delta tN) \\ a_y (\Delta tN) \end{bmatrix} \quad (4.2)$$

In the formula above, the friction produced by constant acceleration is represented by a, the speed of the ball is represented by v, direction of movement is represented by α, forecast period is represented by N, decision-making system operation cycle is represented by Δt, and

$$a_z = \begin{cases} -a\cos\alpha, |v| \geq a\Delta t \\ -v_x / \Delta t, else \end{cases}$$

$$a_y = \begin{cases} -a\sin\alpha, |v| \geq a\Delta t \\ -v_y / \Delta t, else \end{cases}$$

We simplified its parameters according to the characteristics and prediction system of equations and combined with improved algorithm. Then we can get:

$$A_p = M \quad (4.3)$$

$$P = \begin{bmatrix} \tau_{xy}^2 & 0 & 0 & 0 \\ 0 & \tau_{xy}^2 & 0 & 0 \\ 0 & 0 & \tau_{xy}^2 & 0 \\ 0 & 0 & 0 & \tau_{xy}^2 \end{bmatrix} \quad (4.4)$$

$$C=\begin{bmatrix}1&0&0&0\\0&1&0&0\end{bmatrix}\quad Q_P=\begin{bmatrix}\delta_v^2&0\\0&\delta_v^2\end{bmatrix}\quad V=\begin{bmatrix}1&0\\0&1\end{bmatrix}$$

$$W=\begin{bmatrix}0&0&1&0\\0&0&0&1\end{bmatrix}^T\quad R=\begin{bmatrix}\delta_{xy}^2&0\\0&\delta_{xy}^2\end{bmatrix}\quad Z_k=[\,x_{obs}\quad y_{obs}\,]$$

In the process of the soccer motion state variables increase, robot soccer is very close to the football, then we can get:

$$\delta_v=\max\left(\frac{k\cdot(R+r)}{d}\delta_R,\delta_R\right) \tag{4.5}$$

In the formula above, the radius of robot soccer and the football is represented by R and r, the distance between the closest football and the robot soccer is represented by d, while the gain is represented by k, they usually meet $(R+r)\le d$.

THE RESEARCH ABOUT THE REALIZATION PROCESS OF THE SIMULATION EXPERIMENT

Through the analysis of source program, sending and receiving are realized with the implement of the language C, the flow chart as shown in Figure 3:

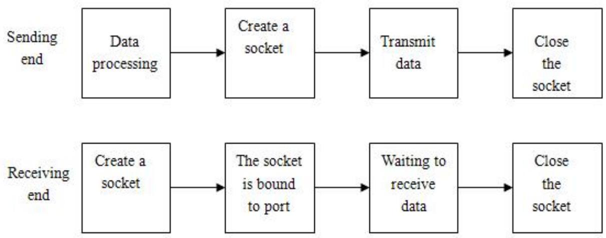

Figure 3:Using UDP protocol to obtain location information of the ball original program flow

Next, achieve football's trajectory by applying the correlation software, the corresponding program diagram is shown in the following figure 4:

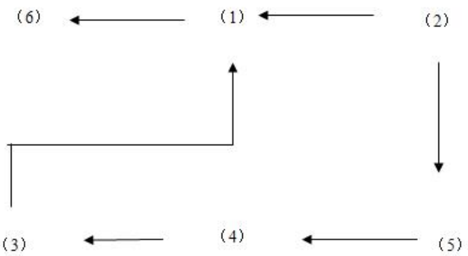

Figure 4: Simulation program flow

Note:

(1): $P_p^-=A_pP_{p-1}A_p^T+W_pQ_{p-1}W_p^T$

(2): $K_p=P_p^-C_p^T\left(C_pP_p^-C_p^T+V_pR_pV_p^T\right)^{-1}$

(3): $P_p=\left(1-K_pC\right)P_p^-$

(4): $\hat{X}_p=\hat{X}_p^-+K_p\left(\hat{Z}_p-h(\hat{x}_p^-,0)\right)$

(5): $z_p=[x_{obs}\quad y_{obs}]$

(6):The initial value of each parameter is initialized

CONFIRMATORY TEST TO IMPROVE THE MODEL

In order to verify the rationality of the improved algorithm, this paper conducted two tests, namely robot soccer act as goalkeeper and play soccer.

First tests conducted the goalkeeper, to prevent the other side of the ball into his team's goal is the responsibility of the goalkeeper, it will make the probability of success greatly improved if the goalkeeper knows e the location of the football in advance.

Table 1: The success rate of two algorithm's goalkeeper goal

	The number of successful intercept	Statistical shooting times	Success rate of goalkeepers
Before improve	15	18	76%
After improved	17	21	91%

Since then the experiment has been carried on about playing soccer robot, and calculated the change in algorithm respectively before and after playing soccer robot shooting.
As shown in table 2:

Table 2: The rate of the algorithm before and after the two robots shots hit

	Number of hits	Statistical hitting times	Hit rate
Before improve	58	78	73.5%
After improved	72	81	88.5%

Through the experiments above we can draw a conclusion : when the football robot do the goalkeeper, after improvement the Kalman filtering algorithm, the success of the robot were increased about 15%，Therefore, the improvement of the algorithm make a contribution.
to robot in hitting the ball.

CONCLUSION

In this paper, Kalman filtering algorithm is proposed through the study of soccer robot in playing process, and expounds the principles of this algorithm, as well as the advantages and disadvantages, in order to make up for its shortcomings, he principle of the algorithm, this paper has presented on the improved Kalman filtering algorithms, and put this algorithm to the system in which the robot soccer plays, and thus established a predictive model of football state, then get the simulation results on the flow for the location of robot soccer. Finally, conducted experiments to figure out whether the improvement of algorithm promoting the development of robot soccer, then get a conclusion that the improved Kalman filtering algorithm greatly improved the success rate of the robot soccer games.

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