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A Novel GA-RBF-PID Control Strategy for Luggage Import Motor Based on Synchronization Control

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Abstract: For the problem of the airport baggage importing from conveyer belt to sorter accurately, this article proposed a novel GA-RBF-PID control strategy based on synchronization control, which applied in airport luggage import motor. Genetic algorithm was presented for turning weight parameters of Radical Basis Function (RBF) neural network to realize optimal control, averting the disadvantage of traditional algorithms which were often trapped to local minima, and the motor synchronous control system was applied to guarantee the speed of the baggage induction sorting motors consistent, and prevent from two baggage getting to a luggage tray at the same time. Simulation results show that this strategy greatly improves the efficiency of baggage importing, guarantee subsequent sorting smoothly. *Copyright © 2013 IFSA.*

Keywords: Luggage import motor, Radial basis function network, Genetic algorithms, Synchronization control, PID.

1. Introduction

Getting stuck, mistakenly picking and other reasons caused luggage lost and delayed, seriously affected the airport's operating efficiency [1]. In this paper, the accuracy of baggage importing is studied. Currently, the traditional PID control algorithm and relatively independent control method was applied in automatic baggage sorting system. With the increasingly well-developed air transport industry, airport operator tasks are increased, especially when the load is not the same, the speed of each independently controlled motor is significantly different. Therefore, for baggage imported motor speed control, conventional PID control algorithm based on fixed parameters, and relatively independent control method is difficult to achieve perfect effect.

In recent years, RBF neural network with its ability of any nonlinear function approximation and self-learning has been widely used in control field. The network parameters and network structure of RBF is critical for its performance, therefore, the traditional method of parameter optimization, such as gradient descent, train slowly and is easy to fall into local optimum .In fact, the search space of network structure and network parameters is infinite [2]. Genetic algorithm is a parallel global search capability, simulated the natural genetic mechanisms and biological evolution, has the ability to converge to the global optimum. Therefore, the PID strategy combined with the RBF neural network, which based on the genetic algorithm, is an effective way to solve the problem of luggage imported motor speed control [3].

Synchronization control means that maintain the speed of several motors synchronization. Master-slave synchronization control mode refers to a motor is the host, another one is the slave motor [4]. Control the host and measure its speed, the resulting rotational speed as the input signal of the slave. The master-slave synchronization control mode is applied to luggage import motor, ensure the following importing motor and the importing motor simultaneously. This paper raised a novel GA-RBF-PID control algorithm, which based on synchronization control, getting a good effect.

2. Luggage Import Motor

2.1. Luggage Import System

In this paper, luggage importing means transporting the baggage from the conveyor line to the sorter. Import the baggage to the high speed baggage tray (BT) on the sorter by preliminary importing conveyor (PIC), importing conveyor(IC) and following importing conveyor (FIC) [5]. During transportation, sorter runs quickly at a certain speed, in order to guarantee luggage to import accurately. The mathematical model of importing system shown as Fig. 1.

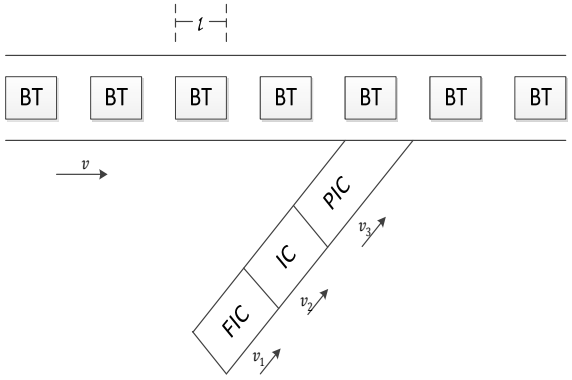


Fig. 1. Baggage sorter simplified model diagram.

In the process of transporting, at first, start the preliminary importing conveyor, wait few minutes, start the importing conveyor and the following importing conveyor. It is the time to stop, stop running importing conveyor and following importing conveyor firstly, in order to ensure the baggage conveying is completed, stop running preliminary importing conveyor. In order to prevent from two baggage getting to sorter simultaneously caused luggage losing, the length of importing conveyor and following importing conveyor must be equal, and the speed of conveyors is equal and constant. When the photoelectric switch on the end of importing conveyor detects baggage, importing conveyor and following importing conveyor stop running, detect the bearer status of luggage tray on the sorter simultaneously, if the baggage sorting tray is empty, calculate the luggage waiting time, preliminary importing conveyor start, wait few minutes, start importing conveyor and following importing conveyor, at last the preliminary importing conveyor convey luggage to baggage tray. The condition of baggage conveying to luggage tray smoothly is that the time from detecting luggage to the luggage getting to the baggage tray and the time baggage running on the belt is equal.

Mathematical model is as follows: If the length of preliminary importing conveyor is l_3, the length of importing conveyor is l_2, the time of baggage running on preliminary importing conveyor is t_3, the time of baggage running on importing conveyor is t_2, L is the distance from the position of detecting luggage to baggage entrance.

$$\frac{L}{v} = t = t_0 + t_2 + t_3 \tag{1}$$

$$t_2 = \frac{l_2}{v_2} \tag{2}$$

$$t_3 = \frac{l_3}{v_3} \tag{3}$$

In conclusion, view from the luggage importing subsystem, the length of conveyors are constant and known, importing conveyor, following importing conveyor and preliminary importing conveyor run constantly, luggage tray always run as the speed of v on sorter, so just configure waiting time, baggage conveying from conveyors to sorter accurately can be guaranteed.

2.2. Luggage Import Motor Synchronous Control Research

Motor synchronous control means the speed of more than one motor can be controlled maintain synchronization, Synchronization in this article refers to the importing motor and following importing motor running as the same speed.

Master-slave synchronous control mode, importing motor (IM) as the host, following importing motor (FIM) as the slave, control the host, and measure its speed, then the resulting speed as the input signal of the slave. The traditional PID control optimize master-slave control system, further genetic algorithm optimized RBF neural network combined with the traditional PID, as Fig. 2 shows.

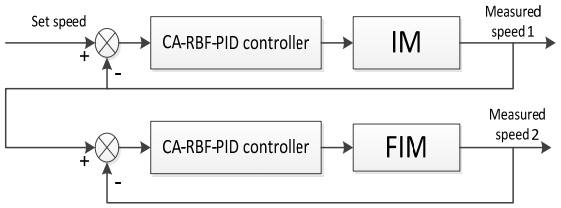


Fig. 2. Based on genetic algorithm RBF-PID controller synchronous speed.

3. PID Control Algorithm Based on RBF Neural Network

3.1. RBF Neural Network

In order to solve multivariate interpolation problem, Powell raised Radial Basis Function in the 1980s, then it was applied to adaptive neural network by some researchers, generate RBF neural network [6-8]. RBF neural network is a three-layer feed-forward network with a single hidden layer. Its structure is simple and training quickly, applied in function approximation and classification problems widely.

1) Network structure

The most basic form of RBF network is a feed-forward network, the role of the input layer is to link network and the outside world, hidden layer achieve non-linear transformation through RBF, neurons in the output layer is linear, thus accelerating the learning speed greatly.

RBF neural network structure shown in Fig. 3.

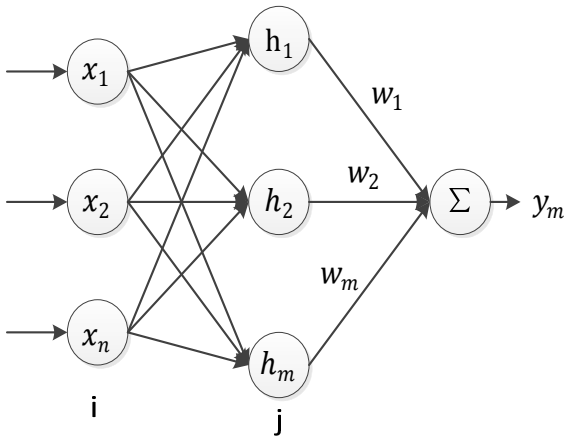


Fig. 3. RBF neural network structure.

2) The controlled object information identification algorithm

In the RBF network structure $x=[x_1,x_2,...,x_n]^T$ as the network input vector. The radial basis vector of RBF network is $h=[h_1,h_2,...,h_n]^T$ generally the RBF refers to Gaussian function.

$$h_j=\exp\left(-\frac{\left\|x-c_j^2\right\|}{2b_j^2}\right), j=1,2,...,m \tag{4}$$

In the network, the central vector of node j is $c_j=[c_{j1},c_{j2},...,c_{jn}]^T, i=1,2,...,n$. The base width vector of network is $B=[b_1,b_2,...,b_m]^T$. b_j is the base width parameter of node j, and greater than zero. The weight vector of network is

$$W=\left[\left[w_1,w_2,...,w_m\right]\right]^T \tag{5}$$

The output of identification network is

$$y_m(k)=w_1h_1+w_2h_2+...+w_mh_m \tag{6}$$

The performance index function of recognizer is

$$J=\tfrac{1}{2}\left(y(k)-y_m(k)\right)^2 \tag{7}$$

According to the gradient descent method, the Iterative algorithm of Output power, wide base node center and node parameters is as follows

$$\Delta w_j(k)=\eta\left(y(k)-y_m(k)\right)h_j \tag{8}$$

$$w_j(k)=w_j(k-1)+\Delta w_j(k)+\alpha\left(w_j(k-1)-w_j(k-2)\right) \tag{9}$$

$$\Delta b_j(k)=\eta\left(y(k)-y_m(k)\right)w_jh_j\frac{\left\|X-C_j\right\|^2}{b_j^3} \tag{10}$$

$$b_j(k)=b_j(k-1)+\Delta b_j+\alpha\left(b_j(k-1)-b_j(k-2)\right) \tag{11}$$

$$\Delta c_{ji}(k)=\eta\left(y(k)-y_m(k)\right)w_j\frac{x_j-c_{ji}}{b_j^2} \tag{12}$$

$$c_{ji}(k)=c_{ji}(k-1)+\Delta c_{ji}(k)+\alpha\left(c_{ji}(k-1)-c_{ji}(k-2)\right), \tag{13}$$

in the formula, β is learning rate, α is momentum factor.

Jacobian matrix (the sensitivity information of the objects output to the control input changes) algorithm is

$$\frac{\partial y(k)}{\partial\Delta u(k)}\approx\frac{\partial y_m(k)}{\partial\Delta u(k)}=\sum_{j=1}^{m}w_jh_j\frac{c_{ji}-x_1}{b_j^2} \tag{14}$$

In the formula, $x_1=\Delta u(k)$

3.2. PID Controller Based on RBF Neural Network

An incremental PID controller, the control error is

$$e(k) = y_d(k) - y(k) \tag{15}$$

The input of PID is

$$\begin{cases} xc(1) = e(k) - e(k-1) \\ xc(2) = e(k) \\ xc(3) = e(k) - 2e(k-1) + e(k-2) \end{cases} \tag{16}$$

Control algorithm is

$$u(k) = u(k-1) + \Delta u(k) \tag{17}$$

$$\begin{aligned} \Delta u(k) = k_p\left(e(k) - e(k-1)\right) + k_i e(k) + \\ k_d\left(e(k) - 2e(k-1) + e(k-2)\right) \end{aligned} \tag{18}$$

The tuning indicators of neural network are

$$E(k) = \frac{1}{2}e(k)^2 \tag{19}$$

k_p, k_i k_d adjust using gradient descent method

$$\begin{cases} \Delta k_p = -\eta\dfrac{\partial E}{\partial k_p} = -\eta\dfrac{\partial E}{\partial y}\dfrac{\partial y}{\partial \Delta u}\dfrac{\partial \Delta u}{\partial k_p} = \eta e(k)\dfrac{\partial y}{\partial \Delta u}xc(1) \\ \Delta k_p = -\eta\dfrac{\partial E}{\partial k_i} = -\eta\dfrac{\partial E}{\partial y}\dfrac{\partial y}{\partial \Delta u}\dfrac{\partial \Delta u}{\partial k_i} = \eta e(k)\dfrac{\partial y}{\partial \Delta u}xc(2) \\ \Delta k_p = -\eta\dfrac{\partial E}{\partial k_d} = -\eta\dfrac{\partial E}{\partial y}\dfrac{\partial y}{\partial \Delta u}\dfrac{\partial \Delta u}{\partial k_d} = \eta e(k)\dfrac{\partial y}{\partial \Delta u}xc(3) \end{cases} \tag{20}$$

In the formula, $\dfrac{\partial y}{\partial \Delta u}$ is the Jacobian information of controlled object, can be obtained through the neural network identification.

The structure of RBF optimized PID control system shown in Fig. 4

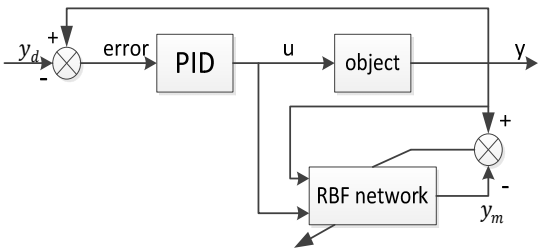


Fig. 4. RBF network tuning PID control block diagram.

4. RBF Neural Network Based on Genetic Algorithm Parameter Optimization

The core of RBF neural network is how to determine the network structure (refers to the number of neurons in the hidden layer) and network parameters, network parameters including network-centric vector c_{ji}, the base width parameter of network b_j and connection weights between the hidden layer and output layer w_j [9-10]. According to the traditional rule of thumb, in this article, RBF neural network structure chose 3-6-1. In generally, if the number of neurons in the hidden layer, the network center and the base width parameter vector is known, the relationship of input to output is linear, at this point, the least square method can be used to determine the connection weights between the hidden layer and output layer w_j.

In this paper, genetic algorithm can be used to optimize network-centric vector of RBF neural network c_{ji} and the base width parameters of network b_j, specific steps as follows:

1) Encoding.

Firstly set some parameters of population size on genetic algorithm $M = 80$, termination evolution algebra G = 100, crossover probability $p_c = 0.60$ and mutation probability $p_m = 0.01$.

Genetic algorithms is used to optimize the parameters of RBF neural network, that network centric vector and network-based width parameter is converted to the manifestation of genetic code string is needed. Genetic algorithms encoding are generally divided into binary code and real-coded, wherein the binary-coded features are clear physical meaning, the operation image, easy to understand. In this paper, binary coded is used. Randomly generate initial population constitute of N chromosomes, each chromosome encoding consist of the network center vector and network-based width parameters

2) The fitness function construction.

In the genetic algorithm, the individual's degree of adaptation to the environment is called fitness, fitness function used to describe the individual's ability to adapt, the larger, the stronger the individual's ability to adapt. Genetic algorithm is based on the individual's fitness to determine the selection probabilities, therefore, the fitness function must be non-negative, in this paper, the inverse of RBF neural network desired output and the square of the actual output is selected to be the fitness function.

$$f = \frac{1}{J}, \tag{21}$$

In the formula, $J = \frac{1}{2}\left(y(k) - y_m(k)\right)^2$.

3) Select Options

Select option is based on the fitness value of the fitness function to determine the corresponding selection probabilities, copy into the new group, if the fitness of chromosomes i is f_i, the chromosome i selection probability p_i.

$$p_i = f_i \Big/ \sum_{i=1}^{N} f_i \tag{22}$$

Cumulative probability

$$q_l = \sum_{i=1}^{l} p_i \tag{23}$$

Common selection process chose roulette selection, selected chromosomes form a new population, specifically as follows:

1) Generate a random float r in (0,1) randomly.

2) If $q_{l-1} < r < q_l$, then the chromosome l is replicated once, the larger the value adaptation chromosome is replicated more times, the next population will be more excellent, small fitness chromosomes get smaller chance to replicated, even no chance.

4) Cross-operator.

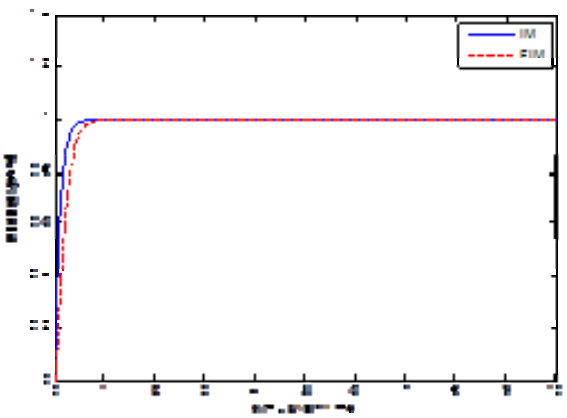
For each chromosome, generate a random float r in (0,1) randomly, if $p_c > r$, the chromosomes are selected, repeated several times, the selected chromosomes will be paired randomly, single-point crossover is the most common and easiest way to cross, specific operations refers to select a point in a particular chromosome randomly, when it is the time to exchange, interchange part of the structure before or after the point. Exchange is completed, the offspring chromosomes instead of the parent chromosomes to form a new population.

5) Mutation.

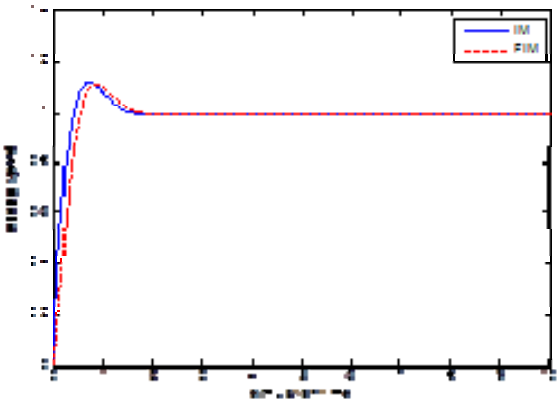
According to mutation probability p_m, mutate some bits of chromosome, in groups, to one point of the chromosome generate a random float r in (0,1) randomly, if $p_m > r$,then vitiate the bite, that code value from 0 to 1 or from 1 to 0.

5. Simulation Analysis

In the MATLAB simulation environment, based on the above analysis, build two motor control simulation diagram. Motor parameters choose the actual motor parameters, analyze the running curve of importing motor and following importing motor. When the two motors are unloaded, two motor speed curve shown in Fig. 5. At 4.3 s, adding load to the importing motor the motor, the following importing motor are unloaded, the two motor speed curve shown in Fig. 6.



(a)



(b)

Fig. 5. The speed curves of the no-load motor. (a) the speed curve of conventional PID control motor. (b) the speed curve of GA-RBF-PID control motor.

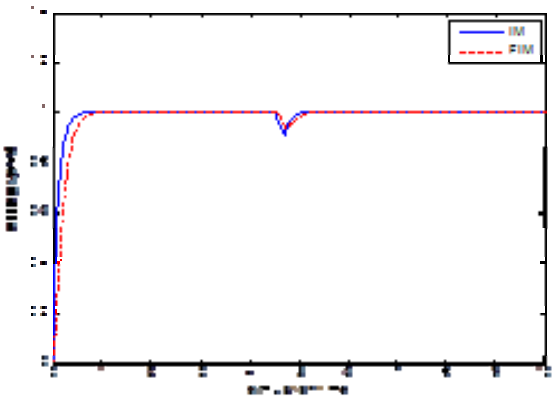
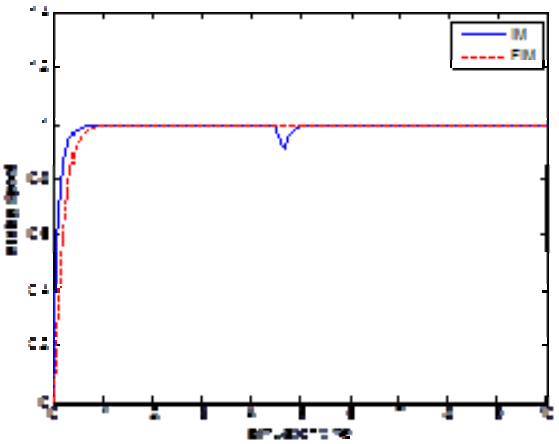


Fig. 6 (a). The speed curve of importing motor plus load motor: the speed curve of GA-RBF-PID control motor.

From the simulation results can be seen, two unloaded motors are controlled separately, as show in Fig. 5, compared with conventional PID control algorithm, RBF-PID control algorithm based on genetic algorithm optimization, its rise time is shorter, settling time is shorter, good dynamic performance, no overshoot, good stability. When importing motor

has loads and the following importing motor unloaded, shown in Fig. 6, the speed of importing motor change significantly, due to be controlled separately, the speed of following importing motor stay the same, thus, individually controlled synchronous motor is not ideal. genetic algorithm optimized RBF-PID based on synchronization control the speed of motor, as shown in Fig. 6(b), at 4.3 s importing motor are under load, the speed of following importing motor can follow the importing motor well.



(b)

Fig. 6 (b). The speed curve of importing motor plus load motor: the speed curve of GA-RBF-PID synchronization control based on motor.

6. Conclusion

This GA-RBF-PID control algorithm based on synchronous control, is applied in import subsystem of airport baggage automatically sorting system [11]. The MATLAB simulation results show that, RBF-PID controller based on Genetic Algorithm has better adaptability and a better superiority, and synchronous motor control system prevent from the loss, stuck and other issues, greatly improve the efficiency of the airport's baggage sorting.

Acknowledgements

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