

The Design and Application of Control System Based on the BP Neural Network

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Abstract. Artificial neural network is composed by a large number of processing interconnected unit. It is a nonlinear, adaptive information processing system. It has self-organizing, adaptive and self-learning ability. And can be used to calculate complex relationship between input and output, thus it has effective control ability. Rubber is the main material in the process of the mixer. It has a great influence on the final product. But at present many factories are added in the rubber by manual control. So this article takes the rubber transport equipment as the object, establish a BP neural network intelligent control system, using neural network self-learning ability and the adaptive ability to deal with uncertain information, to solve the problem of motion control of multiple dynamic input. Through the test of practical application, the system has strong robustness, adaptability, good generality and fault tolerance.

1. Introduction

With the continuous improvement quality of the life, production is constantly development too, especially with the development of China's auto industry by leaps and bounds, rubber industry, especially the rubber tire industry is in rapid development. The demand of mixer which is the initial raw material process of key equipment has a great increase. At present, there still have some enterprises who's mixer technology and equipment are relatively backward in our country. In productive process, the addition of carbon black, rubber and various auxiliary materials still need to rely on workers move to send or manual control equipment^[1]. This will not only greatly affect the efficiency of rubber mixing, strengthen the labor intensity of workers, but also easily caused by artificial product unqualified and waste of resources.

2. The design of the neural network control system

2.1 Analysis of the controlled object

In mixer process all kinds of raw material and adding, rubber is the main. The addition of the rubber is through the conveyor belt, Rubber on the conveyor belt will be transported to the next in the location of the rubber conveyor belt when quality of the rubber under the conveyor belt is enough, it will be transported to the mixer chamber. Rubber need to be tiled under the conveyor belt and with the demand of rubber quality, we bring forward higher requirements of controllability and precision of the control of conveyor belt. Therefore, it is necessary to use modern advanced control theory and technology in industrial production, to enhance the resistance to disturbance and adaptive ability of conveyor belt^[2].

Transport unit driving system is three-phase asynchronous motor, so its control system is motion control of three-phase asynchronous motor. In the actual runtime rubber need to evenly spread on the conveyor belt and rubber strip for uneven. As a consequence, the running speed of the conveyor belt should be according to the position of the conveyor belt and the quality of the rubber. Speed must be adjusted to their relationship in real time. So, motor speed control is not only to get real-time information feedback, still need to test the conveyor location and quality feedback. For real-time rated output speed are obtained.

2.2 The construction of the control system

The principle diagram of the control system model is set up as shown in figure.

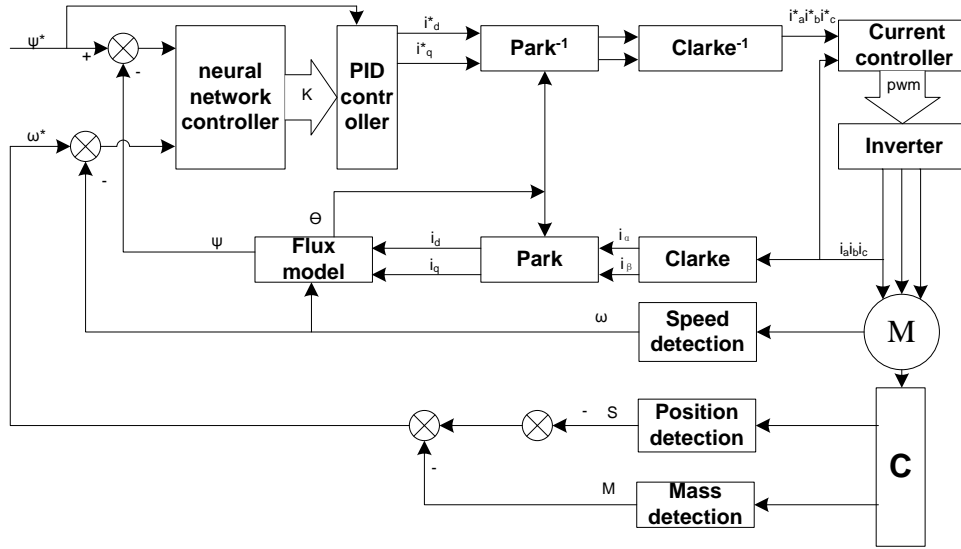


Fig 1 the principle diagram of the control system model

In the first place, measured by the encoder and the weighing sensor we get the actual distance of conveyor belt running S and practical quality M of rubber. According to the given value we can calculate the reference speed ω^* at the moment. Three-phase asynchronous motor stator current, can only detect two of the three phase, which are i_a and i_b , because i_c can be calculated by the formula to $i_a + i_b + i_c = 0$ for connected to the motor windings. And then according to the principle of vector control, the three-phase coordinate system of the stator current i_a, i_b and i_c through Clarke transformation and Park transformation, equivalent to the current component of rotating coordinate system i_d and i_q . That means the asynchronous motor model equivalent to dc motor model to control. Make deviation between reference speed ω^* and actual speed ω and between reference flux chain ψ^* and actual flux chain ψ as reference. And then based on the system running state we can get PID controller coefficient of each link through the neural network. The PID controller calculate the output of each link by typing deviation and the coefficient, which are i_d^* and i_q^* ; i_d^* and i_q^* can be transformed to the three-phase current value i_a^*, i_b^* and i_c^* by Park reverse transformation and Clarke reverse transformation. Current controller output PWM control signals by comparing his actual detected current i_a, i_b and i_c , so we can control the operation of inverter drive three-phase asynchronous motor. [3]

2.3 Real-time reference velocity calculation

As shown, rubber is transported though conveyor belt to another conveyor belt, set a time t and driving distance to S , On the conveyor belt, rubber quality is M . The total length of the Conveyor belt is S' and the need quality of rubber is M' . Considering the other factors affect the transfer process, so we set aside length S_0 , as a buffer. Thus we can calculate the real-time reference velocity ω^* .

$$\omega^* = \frac{(S' - S - S_0) M}{(M' - M) rt} \quad (2-1)$$

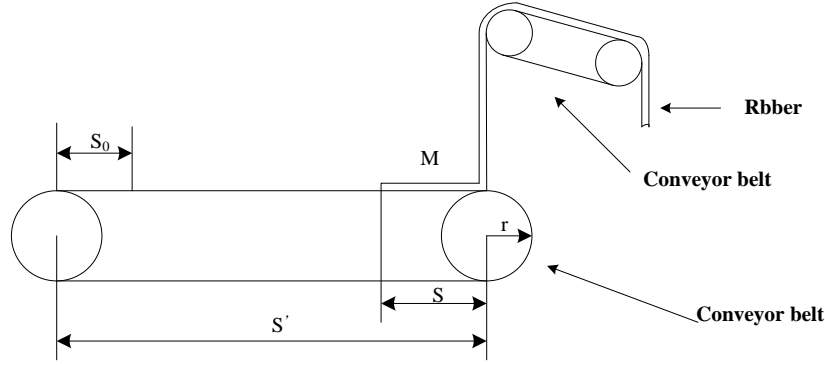


Fig 2 Motion diagram

3. The BP neural network topology

3.1 BP neural network algorithm

The BP neural network is the most widely used network topology. BP (Back Propagation) model is a kind of multilayer forward networks, it has the ability to approximate arbitrary nonlinear function, and the structure and learning algorithm is simple and clear. So in the neural network PID control structure, BP network is always used to establish the PID controller. Through the study of BP neural network of its own, we can find an optimal control law under P, I, D parameters. ^[4] Here is the three layer BP neural network model, it composed by input layer, hidden layer and output layer, its structure as shown.

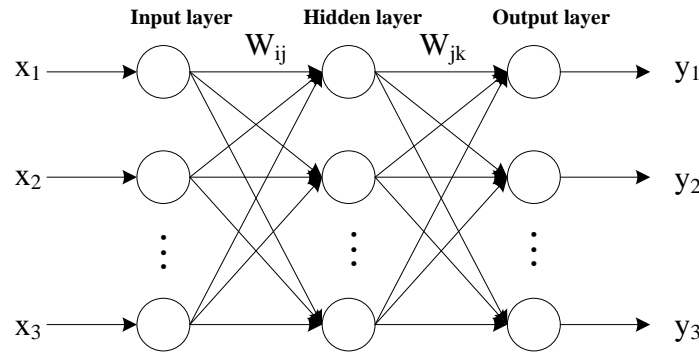


Fig 3 BP neural network model

The input layer node i , The output is equal to the input x_i $i = 1, 2, \dots, n$. Transport input variable values to the hidden layer.

The hidden layer node j , its input h_j , output O_j

$$h_i = \sum_{i=1}^n \omega_j x_i - \theta_j = \sum_{i=1}^{n+1} \omega_j x_i \quad (3-1)$$

$$O_j = f(h_j) = \frac{1}{1 + e^{-h_j}} \quad (3-2)$$

In the formula, $j = 1, 2, \dots, m$, $\theta_j = \frac{\omega_{(n+1)j}}{j}$, x_{n+1}

The output layer node k , its input h_k , output y_k

$$h_k = \sum_{j=1}^m \omega_{jk} O_j - \theta_k = \sum_{j=1}^{m+1} \bar{\omega}_{jk} O_j \quad (3-3)$$

$$y_k = f(h_k) = \frac{1}{1 + e^{-h_k}} \quad (3-4)$$

In the formula, $k = 1, 2, \dots, l$, $\theta_k = \omega_{(m+1)k} O_{m+1}$, $O_{m+1} = -1$

BP neural network's input layer and output layer is the link of controller equipment with the outside world, so the number of nodes in the two layers is decided by the actual application objects, it is not freely choose. So according to the actual condition selection for the input node number is 4, output node number is 3. The number of nodes in the hidden layer related to specific issues of the application object, in different circumstances we should choose different number of hidden layer nodes. In general network hidden layer node number is too small, will not be able to build complex mapping relationship, the network cannot be trained. Number of nodes is overmuch, make network

learning time is too long, can't achieve minimum error. There is no theoretical guidance, so we use empirical formula $h = \sqrt{N+0} + a$ or $h = \log_2 N$ to determine the scope of the number, using experimental method to determine the final number. In this paper we select the logarithmic function, and the number of hidden layer nodes is 6.^[5]

3.2 The selection of learning samples and training algorithms

Add mass distribution for rubber is: 100KG, 120KG, 130KG, 140KG, 150KG, and it is five grades. Actual rubber error is also divided into five levels: 1%, 0.8%, 0.5%, 0.3%, 0%. Each group of data is obtained by many experiments to get Ideal output values for the input. The samples for a total of 80, 60 as the training sample, the remaining 20 as test samples, the training samples are listed in table 1.

Table 1 part of the training sample

	Input Parameter		Out Parameter	
	Quality	Length	Time	Speed
1	116	8	7.8	798
2	108	8	8.2	806
3	132	9	9.1	828
4	144	10	10.5	844
5	122	9	8.8	812
6	126	9	8.6	813
7	138	10	10.2	826
8	106	8	7.4	810
9	148	10	10.4	841
10	136	10	9.7	830

The BP network training process is as follows:

At the start of the training, the network would initialization. The initial weights and the node threshold into a set of random Numbers;

Input the training sample, input of $(X^1, X^2, X^3, \dots, X^P)$, Corresponding output for each input are $(T^1, T^2, T^3, \dots, T^P)$;

Function is calculated in the BP neural network algorithm, we compared the actual output $(Y^1, Y^2, Y^3, \dots, Y^P)$ with rated output $(T^1, T^2, T^3, \dots, T^P)$, The error step by step reverse transmission toward the input layer, with the values of neural network to modify the node threshold;

Make actual output values and the rated output value as far as possible to reach, until reduced to an appropriate threshold value. The error function adopts:

$$E_k = \frac{1}{2} \sum_{k=1}^l (t_k - y_k)^2$$

η is the step length, weight and node threshold correction formula is respectively:

$$\omega_{jk}(n_0 + 1) = \omega_{jk}(n_0) + \eta \sum_{\lambda=1}^P \delta_{jk}^{\lambda} o_j^{\lambda} \quad (3-5)$$

$$\omega_{ij}(n_0 + 1) = \omega_{ij}(n_0) + \eta \sum_{\lambda=1}^P \delta_{ij}^{\lambda} o_j^{\lambda} \quad (3-6)$$

$$\delta_{jk}^{\lambda} = (t_k^{\lambda} - y_k^{\lambda}) y_k^{\lambda} (1 - y_k^{\lambda}) \quad (3-7)$$

$$\delta_{ij}^{\lambda} = \sum_{k=1}^l \delta_{jk}^{\lambda} \omega_{jk} o_j^{\lambda} (1 - o_j^{\lambda}) \quad (3-8)$$

When the number of training sample is P, the total error E should satisfy:^[6]

$$E = \frac{1}{2N} \sum_{k=1}^l E_k \leq \varepsilon \quad (3-9)$$

3.3 Test result

Epsilon = 0.001, and the train the network. After the completion, 20 groups of test data to test and accuracy reached more than 90%. So network topology conforms to the actual requirements.

4. Function realization

The working process of the BP neural network is composed of two parts. The first stage is the learning phase. At this stage the BP neural network according to the training sample and given learning rule revision modify the weights between each node and the threshold. So that the output

of the neural network function to meet the set requirements, and the output error is minimum. The second stage is the actual working period. In the meantime the parameters obtained by using neural network training could be used to get the corresponding output from the input through the network. The actual work stage is the most important stage to judge the effect of the use of BP neural network, in the stage we can find out whether the BP neural network can achieve the ideal results. The effect of the actual work, will be influenced by the number of training samples, distribution of the samples and the rules of learning sequence. During the actual work, fluctuations in the input due to the external environment disturbance, will cause the output instability. So in the practical application stage, we usually increase or optimize learning samples to improve the performance of the network.

In the present paper, Processor of the control system is a eight single chip microcomputer. Considering the BP neural network algorithm is relatively complex, programming is heavy, so in the system development, will have computer to complete the learning algorithm of neural network. The function of single chip microcomputer is dealing with neural network work in the phase of the actual work.

5. Summary

This paper establish a control system based on BP neural network through the analysis of the add rubber mixer process. The distributed storage and parallel processing information of BP neural network can simplify the modeling process. To eliminate the error caused by wrong selecting model and parameters, can achieve real-time control, and improve the performance of the control system. In this paper, through off-line way to adjust the network weight and threshold, so that increase the generality of intelligent controller, ensure the performance of the controller, enhance fault tolerance.

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