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Research of PID Control Algorithm Based on Neural Network

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Abstract

Through the research on the existing BP network and PID control technology, for the defects of general BP algorithms such as slow convergence and easy to fall into local minimum, this paper presents an improved BP algorithm, and based on this algorithm proposes an implementation scheme of PID control system, the results show that the scheme can not only improve the convergence speed of the algorithm in the training process, and the trained BP neural network also has strong adaptive and self-learning capability, which further improves the performance of PID controllers.

Keywords: PID control; neural network; BP algorithm

1. Introduction

With the development of industry, control objects are continuously complex, especially for the unknown parameters or slow changes in large delay, time-varying, nonlinear complex systems, with delay or random interference, but the conventional PID control parameters will have no changes after completion, resulting in the parameter variations of controlled objects can not be tracked in real time, can not meet increasing requirements of control quality in the production process, researchers therefore enhanced a variety of improvements for PID control, mainly in two aspects: one is the improvement of structure, namely,variable structure control [1]; on the other hand, combining the fuzzy theory, artificial neural networks, genetic algorithms and other intelligent control theories with conventional PID control, to play their respective advantages, that is, the so-called intelligent PID control. Intelligent PID control does not depend on precise mathematical model, has better robustness for system parameters, so it has good prospects.

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At present, the theory system of intelligent control has not been established, but the neural network control, fuzzy control, expert systems, genetic algorithms have become recognized intelligent control method, and has achieved many successful applications. Therefore, the neural network application in automatic control is the demand of automatic control development. Neural network control is the combination of neural network and control theory, and becomes one of the forefront subjects in intelligent control field.

2. Pid Control Principle

Since computer accessed in control field, using digital computer to replace simulated computer adjuster to compose computer control system, not only can use software to achieve PID control algorithm, and can use the computer's logic function to make PID control more flexible. Digital PID control in the production process is the most commonly used control method, widely used in metallurgy, machinery, chemical and other industries [6]. In the simulated control system, the PID controller controlled according to the proportion of deviation (P), integral (I) and differential (D) is the most widely used automatic controller, the control principle as shown in figure 1.

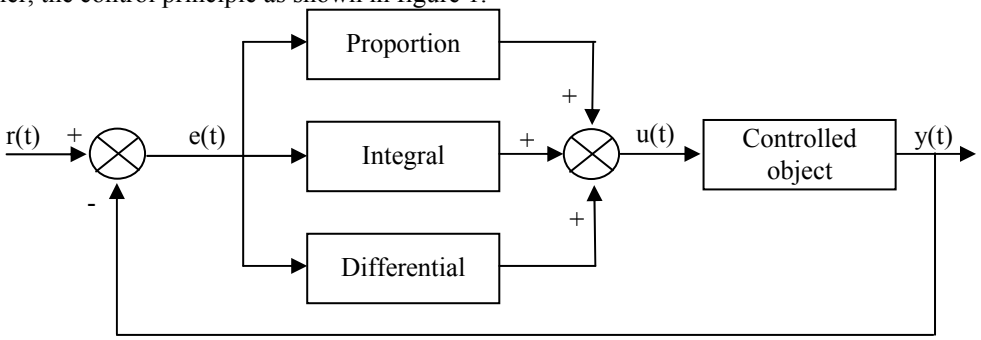

Figure 1. PID control principle

Among them, $r(t)$ is the given value , $y(t)$ is the actual output value, $e(t)=r(t)-y(t)$, PID control law is: $u(t) = K_p[e(t) + \frac{1}{T_i}\int_0^t e(t)dt + \frac{T_d de(t)}{dt}]$ k_p is scale coefficient, T_i is integral time constant, and T_d is differential time constant.

Therefore, PID controller has the following characteristics: principle is simple, easy to achieve, is a basic controller can meet the majority of actual needs; controller can be applied to a variety of different objects, the algorithm has strong structural robustness, in many cases, its control quality is not sensitive to the structure and parameter perturbations of controlled object[7] . However, the main limitation of PID control is its dependence on the controlled object, generally needs to advanced know the mathematical model of the controlled object to design. And in practical industrial control, due to that the controlled object has non-linear, time variability and other characteristics, so it is difficult to establish accurate mathematical model or the characteristic parameters are difficult to obtain online, making its application is limited.

3. Optimization of Bp Neural Network Algorithm

3.1. BP neural network topology structure

With the continuously emerging new control ideas and means in the control field, artificial neural network as a new type of information acquisition, description and handling, are causing process control attention. Neural network has capabilities to approximate any nonlinear function relationship and more convenient learning means, so that it can be used to be a new method of complex industrial. process modeling[2] . BP network is one of the forward feedback networks, also one of the most widely used networks, the network structure as shown in figure 2.

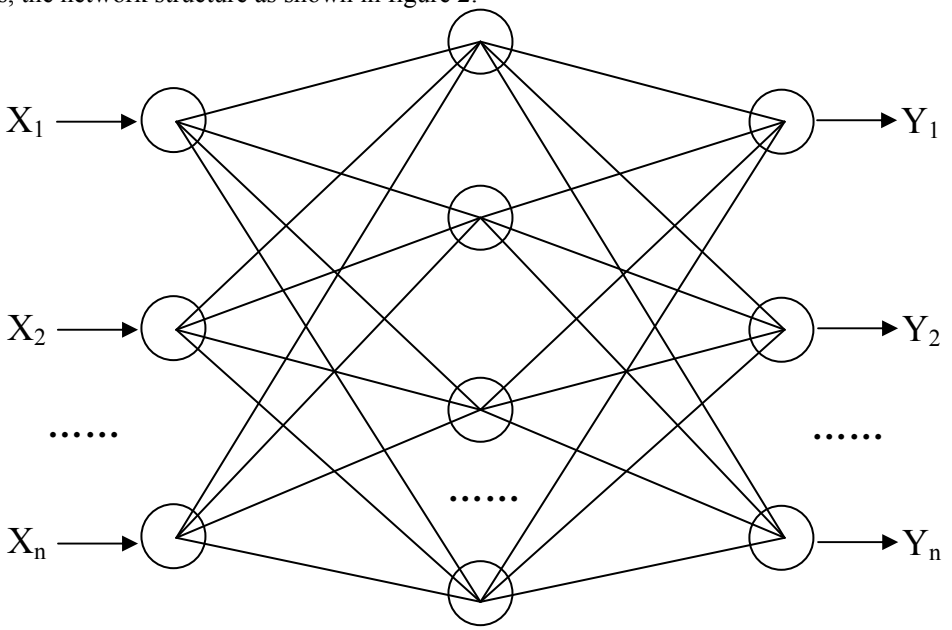

Figure 2. BP neural network structure

From the information flow in operation process, neural network based on BP algorithm is a forward feedback network. This network only provides a lot of neurons which have simple processing capabilities, and the combination of them makes the network have complex nonlinear mapping ability and no feedback, so it does not belong to a nonlinear dynamic system, but rather a nonlinear mapping. However, because of its theoretical integrity and wide application, it still has important significance, but also has the following problems: BP algorithm converges along the mean square error gradient descent direction, but the gradient curve of the mean square error has many local and global minimum, which makes the neural network easy to fall into local minimum; BP learning algorithm convergence rate is very slow, which will waste a lot of time; and the network generalization is poor [4]. To solve these problems, it needs to make the necessary improvements on the basic BP algorithm, to speed up the convergence speed, thus to achieve optimization.

3.2. BP neural network topology structure

BP network uses the basic BP algorithm, that is, the negative gradient algorithm, which adjusts the

weights and thresholds along the negative gradient direction of the network performance function. But in the algorithm the adjacent iteration search directions are orthogonal, when near the extreme there will be oscillation. Although this is the fastest method to reduce the network performance function value, but its convergence is slow and is easy to fall into local minimum. The improved conjugate gradient algorithm can improve the convergence rate without increasing the complexity of the algorithm, and also can achieve the global optimum along the conjugate direction, that is, the global extreme point. It requires the use of linear search in the algorithm process to ensure the convergence speed.

Gradient vector and the subspace consisting of direction vectors are orthogonal, each iteration time, the dimension of subspace plus 1, learning rate will change along the search direction, and its size depends on the linear search results. If the conjugate gradient method in the first k+1 times of learning rate makes the objective function value increased, that is, when the search direction of a step becomes non-descent direction because of the error accumulation, in accordance with the global convergence theorem, the objective function in the whole iterative process must be continuously declined [5]. Therefore, to set the first k+1 times of learning rate to be 0, then the implementation of an interleaved step, that is, equivalent to the implementation of a steepest descent step for the conjugate gradient method, and when iteration is completed, the results will be converged to the global minimum[3] .

Thus, it can be seen that the improved conjugate gradient algorithm also takes into account the convergence speed while ensuring the global convergence. In order to ensure the conjugacy of search direction, the initial search direction takes the negative gradient direction; and when the error accumulation makes the search direction of a certain step becomes non-descent direction, it also will again start follow-up search with a negative gradient direction.

4. Pid Control Algorithm Based on Bp Neural Network

Using neural network PID controller to replace the ordinary PID controllers can make the error between the system output and expected values minimum. The structure of PID control system based on BP neural network as shown in figure 3:

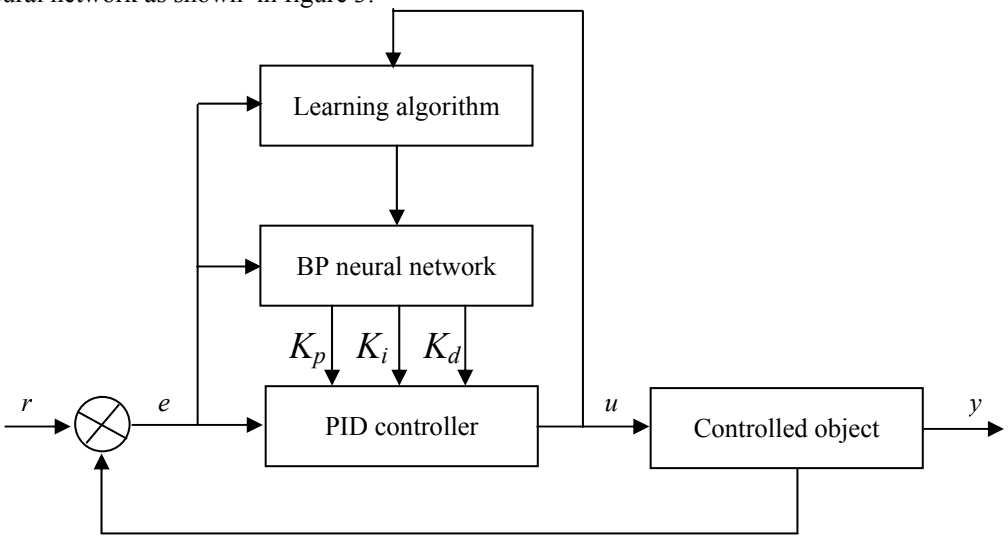

Figure 3. PID control system structure

It can be seen from figure 3: the controller consists of two parts, namely, conventional PID control and

neural networks, in which, the conventional PID directly controls the controlled object with a closed loop, and its control parameters K_p , K_i and K_d are online adjust mode; neural network is to adjust the parameters of PID controller based on the operational status of the system, to achieve a performance optimization, making the output of the output neurons corresponding to the three adjustable parameters of PID controller[8] . Through neural network self-learning and weighting coefficient adjustment, the neural network output will corresponds to the PID controller parameters under a certain optimal control law. The specific implementation of PID control algorithm based on BP neural network as shown in figure 4:

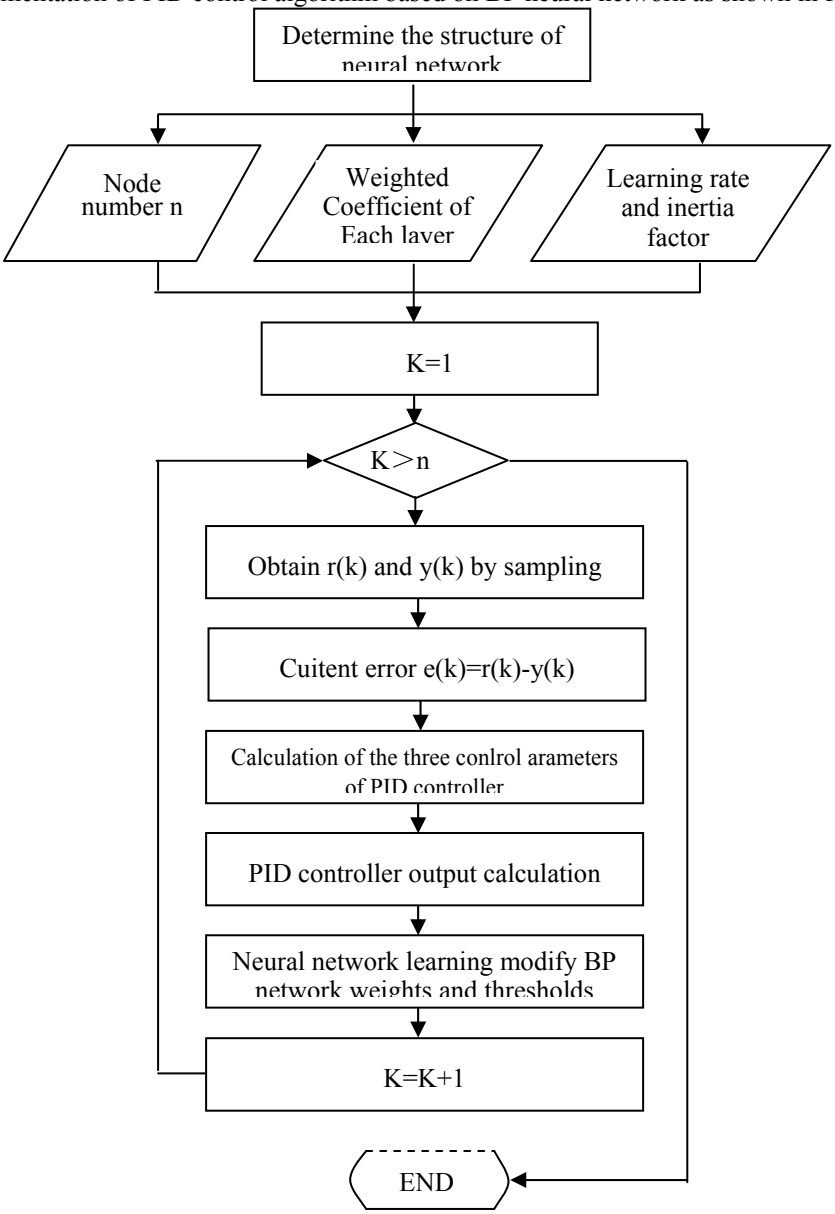

Figure 4. PID control algorithm implementation process

5. Conclusion

BP neural network is a neural network structure commonly used. It can approach any nonlinear function with arbitrary precision, has good approximation performance and simple structure, and thus is an excellent neural network. Therefore, BP neural network applied to PID control has its unique advantages. In this paper, for the defects of general BP algorithms such as slow convergence and easy to fall into local minimum, an improved BP algorithm is proposed, and based on which an implementation scheme of PID control system is presented, the results show that the scheme can not only improve the convergence speed of the algorithm in the training process, and the trained BP neural network also has strong adaptive and self-learning capability, which further improves the performance of PID controllers.

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