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Simulation Studies of CMAC-PID Combined Control for Electro-hydraulic Position Servo System

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Abstract. An electro-hydraulic servo system is taken as control object, the control strategy combining CMAC network with the PID controller is discussed. The inverse dynamic control is realized using CMAC neutral network as feed-forward controller, the PID controller is acted as feedback controller to subdue the turbulence and guarantee its stabilization. Output signals from the CMAC network and from a conventional PID controller are integrated to constitute an overall output signal, which then acts on the controlled object. Thus, good regulating performance by itself is guaranteed. The AMESim model of the electro-hydraulic servo control system is established, and the collaborative simulation of hydraulic system model and control algorithm is implemented. Simulation results show that this control strategy is effective and practical.

Introduction

Electro hydraulic position servo system, due to its high control accuracy, response speed, large output power, signal processing, flexible, easy to realize all kinds of parameters of feedback, etc., now has been widely used in various fields of technology. However, due to the hydraulic servo system exists such as dead zone and friction non-linearity is more complex, the object parameters will change with changes in environmental conditions, and many electro-hydraulic servo system are the external load disturbance, these perturbations are usually uncertain and unknown, so the traditional control algorithm is difficult to meet the control performance requirements.

CMAC is a neural network model proposed by Albus in 1975, which has the characteristics of nonlinear and self-learning ability. In recent years, CMAC has been widely used in real time control, pattern recognition, non-linear time series analysis and so on. In this paper, the CMAC neural network and PID composite control strategy are discussed, and it is applied to the real-time control of the electro-hydraulic position servo system, and the effectiveness of the algorithm is verified by simulation.

Working Principle of CMAC Network

The realization of CMAC network:

Firstly, the input space S is divided into many sub spaces, and each adjacent sub space is overlapped with each other.

Secondly, the input vectors of S fall into the corresponding sub space under the function of the field function, and each sub space is activated by the two maps to activate the N storage unit.

Finally, the weights of these elements are stored to generate an output of CMAC.

CMAC neural network architecture is shown in figure 1 In the graph, S is the input vector, A is the associative unit vector, F (S) is the output function, $a_1 \sim a_n$ are the storage selection vector , and $w_1 \sim w_n$ are the weights in the actual memory. From the graph, it can be seen that the CMAC is essentially an intelligent adaptive search technique, which is composed of multi-dimensional discrete input space and complex nonlinear function.

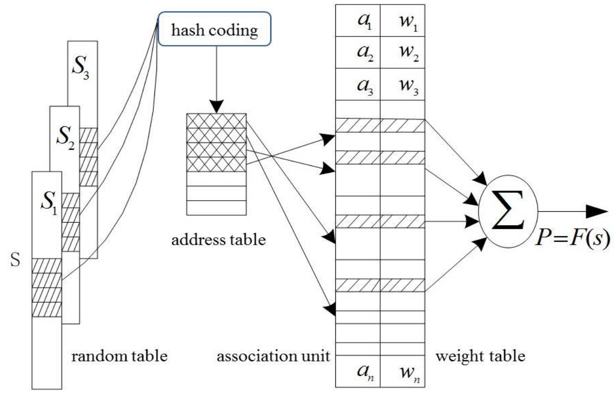

Figure 1. CMAC neural network structure.

The mapping is divided into two processes:

First mapping $S(x)$ is the input state space X of arbitrary point x as the address mapping variables to the concept memory A, X to a mapping is by rolling the combination, and its principle is the vector space is similar to the input and in the output space to more similar, X in a has associative characteristics, Lenovo cell number n, n is also known as the size of the generalization and by Lenovo to unit and its value is 1, the rest to 0. The address of the A space is a virtual address. If the input vector dimension less, virtual address can and physical address correspondence; if input vector dimension is large, the storage space of concepts a have may be very huge, to enable the network to achieve the physical, the pseudo random mapping method, namely Hash-coding method, a mapping to a smaller actual storage space A_p and corresponding physical unit number is N_g. This is usually a kind of mapping, that is, every vector X in x_i corresponds to a few of the identified cells in the A_p.

Second mapping P is used to calculate the output value

$$y = P(a) = a^T w = \sum_{i=1}^{N_g} w_i a_i \tag{1}$$

In the formula, j is the address of the A_p corresponding to the i.

CMAC learning is based on gradient descent method, which can be described as

$$\Delta w_j = \frac{\beta}{N_g}(\hat{y}_s - y_s) \tag{2}$$

In the formula, s is the sample mark, $\triangle w_j$ is the weight correction, β is the learning rate, $0 < \beta < 1$.

Compound Control Strategy Based on CMAC

Composite control is based on the feedback control, the control signal of the differential system as a system of additional input. This kind of hybrid control with feedback and feed-forward can improve the tracking precision and dynamic performance of the system. Considering CMAC neural network has strong nonlinear approximation ability and strong self-learning ability, taking into account the CMAC learning fast, CMAC neural network is chosen as a forward link, in order to improve the compensation effect of the composite control.

1. Electro hydrauli
2. AMESim
3. Simulink
4. CMAC-PID
5. Albus

Controller Structure

CMAC and PID compound control structure as shown in Figure 2, the system through the CMAC and PID compound control to realize feed-forward, feedback control, so as to enable the controlled object dynamic inversion control, CMAC controller using the input layer, hidden layer and output layer of the three layer neural network, through training to optimize the weights, the feedback control is realized by using the conventional controller, guarantee the system stability and disturbance rejection.

Controller Learning Algorithm

CMAC uses a tutor's learning algorithm, the end of each control cycle, calculate the corresponding CMAC output $u_n(k)$, and with the total control input $u_n(k)$ comparison, correction weight, into the learning process. The purpose of the study is to make the total control input and the difference between the outputs of the CMAC. After CMAC learning, the learning of the CMAC only depends on the error of the measured value and the value of the change. The control algorithm of the system is

$$u_n(k) = \sum_{i=1}^{c} w_i a_i \tag{3}$$

$$u(k) = u_n(k) + u_p(k) \tag{4}$$

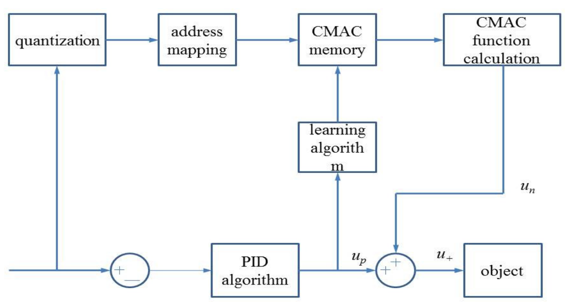

Figure 2. CMAC and PID composite control structure diagram.

In the formula, a_i is a binary choice vector, c is the norm parameter of CMAC network, $u_n(k)$ generates the corresponding output, $u_p(k)$ is the output of the PID controller.

CMAC adjustment index is shown as

$$E(k) = \frac{1}{2}(u(k) - u_n(k))^2 \cdot \frac{a_i}{c} \tag{5}$$

Using gradient descent algorithm, the weight adjustment formula of CMAC is obtained:

$$\Delta w(k) = \eta \frac{u(k) - u_n(k)}{c} a_i = \eta \frac{u_p(k)}{c} a_i \tag{6}$$

$$w(k) = w(k-1) + \Delta w(k) + \alpha(w(k) - w(k-1)) \tag{7}$$

In the formula, η is the network learning rate, $\eta \in (0,1)$, and α is the inertia weight, $\alpha \in (0,1)$.

Simulation Method and Examples

AMESim Modeling of Electro Hydraulic Position Servo Control System

In order to improve the accuracy of the simulation, it is more effective to test the control algorithm. This paper is based on the AMESim simulation software for the hydraulic system modeling.

AMESim is a French imagine company to develop advanced engineering system simulation modeling environment, which is fluid, liquid, gas, machinery, control, electromagnetic engineering system provides a better simulation environment.

In the process of modeling, the sketch mode, sub-model mode, parameter mode and run mode are required. According to the actual hydraulic circuit, in sketch mode selection of various hydraulic components, can also use the HCD Library of model components needed to build, then according to the inter element connections connect the components into complete hydraulic loop; select the specific models of all components and pipe in the sub-model mod; detailed parameter in the parameter mode setting element; in run mode to set up the simulation time and step length. Then the simulation can be run.

Figure 3 shows a simplified AMESim model for the typical electro-hydraulic servo system, which consists of a servo valve, a hydraulic cylinder, etc.

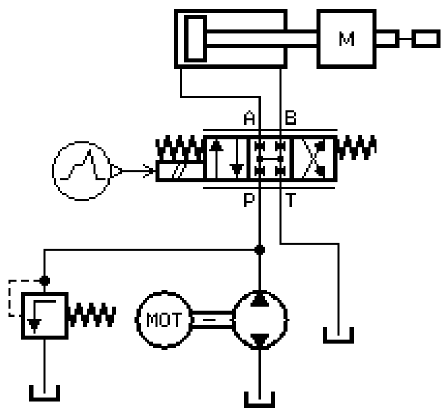

Figure 3. AMESim model of electro hydraulic position servo system.

Realization of Collaborative Simulation Method

The hydraulic system simulation model is built based on AMESim environment, using Interface inter-face to construct control model Simulink is an icon, set number of input, output port, the definition of the icon name, interface type, and then the model with the corresponding interface icon part is connected to, after the completion of the selection of each element type, setting the parameters of each element, system the model has been built to run the above control module generates the corresponding link file, and then through the S-Function module in SIMULINK S-Function is added to the Simulink model, modify the file name and set parameters of the system calls the link file, then the model control algorithm in Simulink connected to the AMESim in Controller, because S-Function can interact with the solver in AMESim, can make the real-time data exchange with the AMESim model in the simulation process, so as to realize the organic combination of AMESim and Simulink.

Simulation Results

The call of the function M form to write CMAC neural network controller and the PID controller, under the Simulink environment to establish compound control model, as shown in Figure 4, figure control object for the AMESim model of hydraulic system s function of the file, the input is defined as the control signal of the servo valve, the output is defined as the displacement of the piston. The CMAC control function m using clock implementation the initialization of the weights of the neural network, the PID control function m by persistent command to realize dynamic parameters maintained by global command parameters to achieve the sharing, the clock to achieve the parameter initialization.

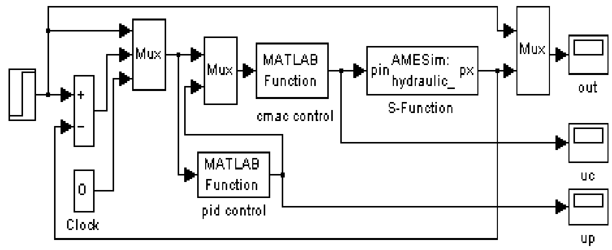

Figure 4. Simulink model based on CMAC + PID composite control system.

Simulation results as shown in Figure 5 for comparison, the step response of conventional PID control is given, we can see the CMAC-PID compared to PID control makes smaller overshoot and high control precision.

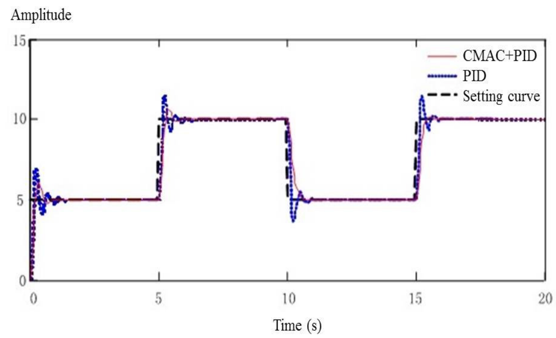

Figure 5. Comparison chart of simulation results.

Conclusion

In view of the characteristics of nonlinear and uncertainty of electro-hydraulic servo control system, the application of CMAC-PID adaptive control strategy is proposed. A typical electro-hydraulic servo control AMESim model of the system, through the hydraulic system model and control algorithm model of collaborative simulation. The results show that electro hydraulic position servo control in the CMAC compound controller with dynamic performance is better than conventional PID control.

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