APPLICATION OF SMITH PREDICTOR USING NEURAL NETWORK TO TERMINATE DELAY PROCESS IN PID CONTROLLING TWO-LINK ROBOT ARM

ỨNG DỤNG MẠNG NEURON TRONG BỘ DỰ BÁO SMITH CHỐNG TRỄ CHO BỘ ĐIỀU KHIỂN PID ĐỐI TƯỢNG CÁNH TAY MÁY HAI BẬC

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TÓM TẮT

Cánh tay máy hai bậc là một đối tượng MIMO điển hình trong việc kiểm chứng các giải thuật điều khiển. Việc điều khiển đối tượng không có quá trình trễ bằng giải thuật PID đã được kiểm chứng thành công. Tuy nhiên, trong thực tế, quá trình trễ luôn xảy ra như việc trễ do điều khiển qua mạng, trễ do việc xử lí cảm biến hồi tiếp về quá chậm. Khi đó, bộ điều khiển PID không còn đưa ra đáp ứng tốt. Một giải pháp được đề ra trong khuôn khổ bài báo này là ứng dụng một bộ dự báo Smith Predictor có ứng dụng mạng neuron để đảm bảo bộ điều khiển PID vẫn cho đáp ứng tốt ngay cả khi quá trình trễ là đáng kể. Kết quả được kiểm chứng thông qua kết quả thực nghiệm.

ABSTRACT

Two-link robot arm is a typical MIMO system in testing control algorithm. Using PID controller for non-delay systems has been successfully researched. In reality, delay process always happens, such as delay of network, delay of slow processing feedback of sensor. Because of that, PID controller does not respond well anymore. A solution suggested in this paper is application of a Smith Predictor using neural network to ensure that PID controller responds well even though delay process is remarkable. The result is proved doing well over experiment.

Keywords: *two-link robot arm, Smith predictor, neural network, PID controller.*

I. INTRODUCTION

Two-link robot arm is a typical multi input – multi output (MIMO) system which has been the usual one for testing control theories in laboratory and industry. Several control theories have been tested successfully for two-link robot arm such as PID, fuzzy logic, adaptive, etc. [6], [7], [8], [9]. However, these controllers only can control system well in no-delay conditions. Delays are quite common in this kind of system, it can occur in sensor processing, data transmission via network. These delays make controller respond unpunctual to system's changes. As a result, control signal is not suitable for current system's conditions. It is difficult to obtain satisfactory performance of control systems in delay conditions.

To overcome the influence of delay in feedback signal transmission, a proposed solution is using Smith predictor. Smith predictor aims to establish a simulative object corresponded with the real one (transfer function, neural network, predictive mathematical equation of object). Some researches on linear systems [1], [2] had established simulative object through transfer-function. However, that is Single Input – Single Output (SISO) system and transfer-function is mainly formed by model parameters system's measurement which is influenced by many factors (such as un-measurable system's parameters, incorrect mathematical equation of system because of complex computation) to be inaccurate. It is impossible to measure exactly with a complicated MIMO system.

Neural network have been researched [4], [5] and successfully applied in real objects identification [3]. Using neural network to form a simulative object in Smith predictor was successful in this article. Communication lags do not influence quality of control. Results had been demonstrated by experimental models which is a two-link robot arm system.

II. THEORETICAL BASIS

1. Two-link robot arm model

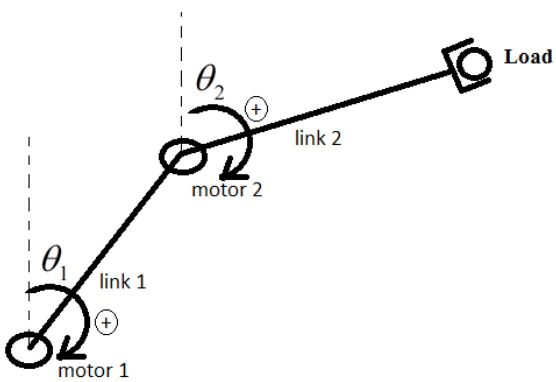


Fig. 1: The two-link robot arm model.

Figure 1 shows the schematic drawing of two-link arm which consist of two flexible links: link 1 and link 2. By controlling of two links above, load location can be controlled to reach to the desired position in space.

Two-link robot arm is MIMO system with two inputs – two outputs. Two SISO controller can be used to control according to separation principle, each one will control operation of a link in arm.

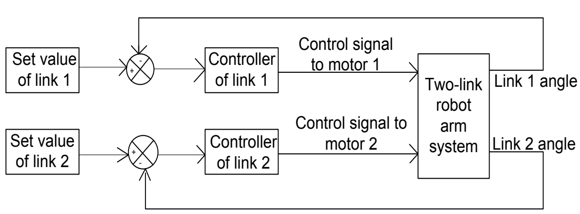


Fig. 2: The control scheme of two-link robot arm.

2. Smith Predictor

The Smith predictor, invented by O. J. M. Smith in 1975, is a type of predictive controller for systems with pure time delay. The usage can be summarized as follows:

Suppose the plant consists of G(z) followed by a pure time delay z^{-k}.

As a first step, suppose we only consider G(z) (the plant without a delay) and design a controller C(z) with negative feedback control as follows:

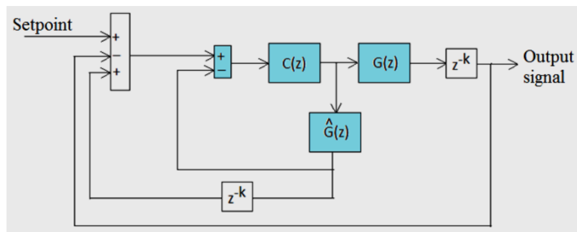


Fig. 3: The control scheme with discretized Smith predictor.

Then, a closed-loop transfer function is:

$$H(z) = \frac{C(z)G(z)}{1 + C(z)G(z)}$$

When the system delayed, our objective is to design a controller $\bar{C}(z)$ which satisfy control demands for the plant $G(z)z^{-k}$. So that the new closed loop transfer function $\bar{H}(z)$ equals to $H(z)z^{-k}$. Then, transfer function of system controller is:

$$\bar{C} = \frac{C}{1 + CG(1 - z^{-k})}$$

If $\hat{G}(z)z^{-k}$ approximates to $G(z)z^{-k}$, then the controller C(z) generates the correct control action, despite time delay.

According to the control scheme in Fig. 3, $\hat{G}$ can be represented by a trained neuron which is equivalent to use system. In that case, delay must be define and C(z) is the used controller. Therefore, C(z) block is the discrete-time PID controller.

Consequently, the building Smith predictor problem turns into the identifying problem using neural networks.

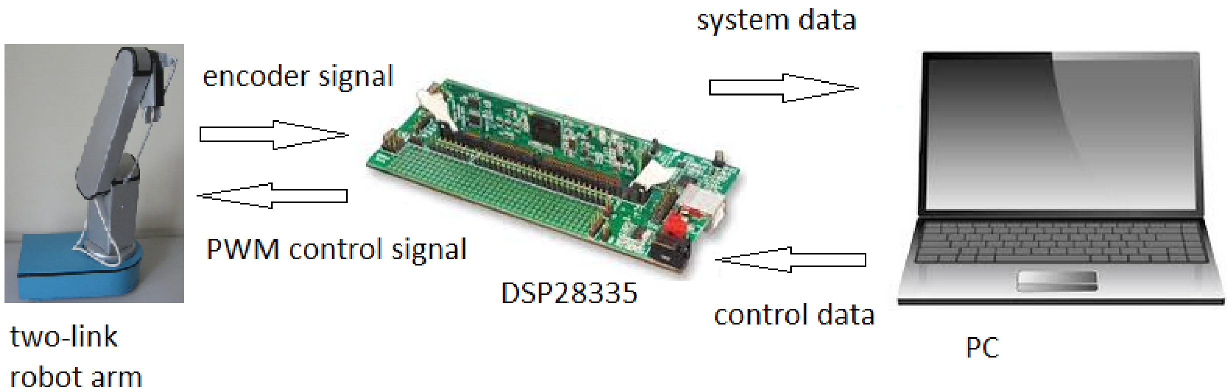
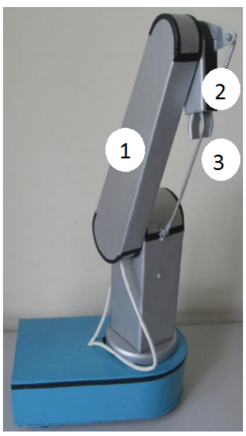


Fig. 4: Hardware control scheme

3. Object recognition using neural network

The two-link robot arm model in practical:



1: link 1 arm
2: link 2 arm
3: gripper

Fig. 5: The two-link robot arm model in practical.

Supposed form of input signals are shown in Figure 6 and Figure 7.

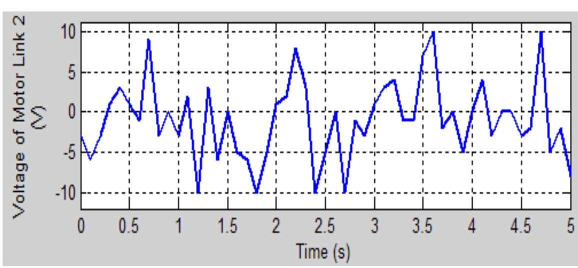


Fig. 6: Control signals to identify of link 1.

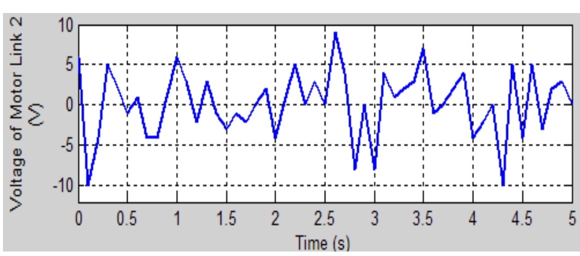


Fig. 7: Control signals to identify of link 2.

From the input signals $u_1(k)$ and $u_2(k)$ above, we collected the signals $y_1(k-1)$, $y_1(k-2)$, $y_1(k-3)$, $y_2(k-1)$, $y_2(k-2)$, $y_2(k-3)$ according to the signal recognition scheme as follows:

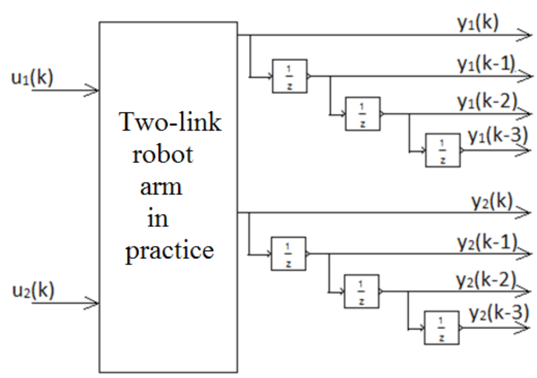


Fig. 8: Diagram of collecting signal to identify.

Since then, we continue to train the neural network described system with the selected input as follows:

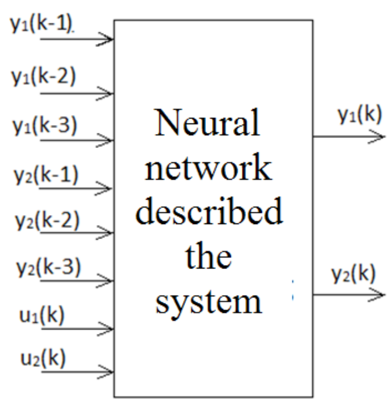


Fig. 9: *Block diagram describes the identification neurons.*

Neural network training results

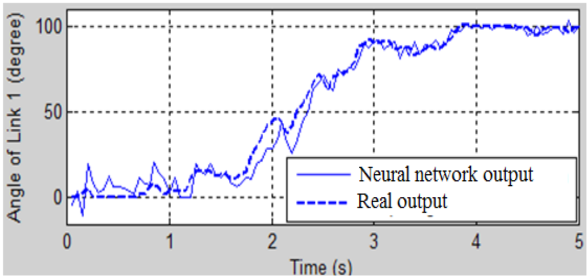


Fig. 10: Predicted identification signal and real signal of link 1.

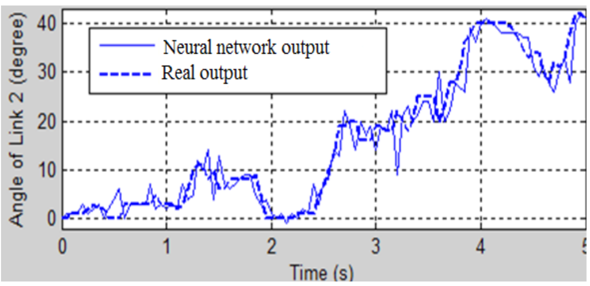


Fig. 11: Predicted identification signal and real signal of link 2.

III. EXPERIMENTAL RESULTS

The identified neural network, applied Smith control scheme in Fig. 4, with sample time Ts = 0.1s and selected PID control parameters produced results as follows:

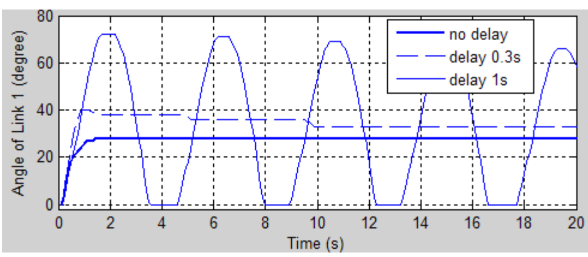


Fig. 12: Angle of link 1 with PID controller without Smith predictor.

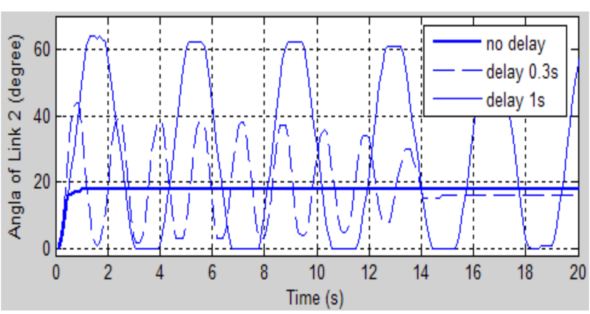


Fig. 13: Angle of link 2 with PID controller without Smith predictor.

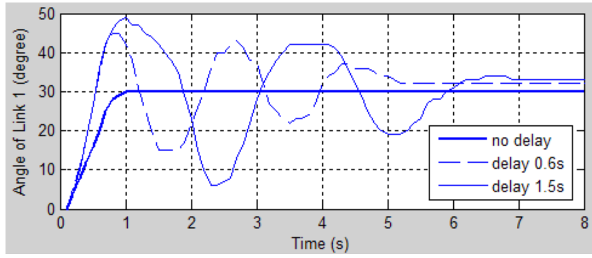


Fig. 14: Angle of link 1 with PID controller with Smith predictor.

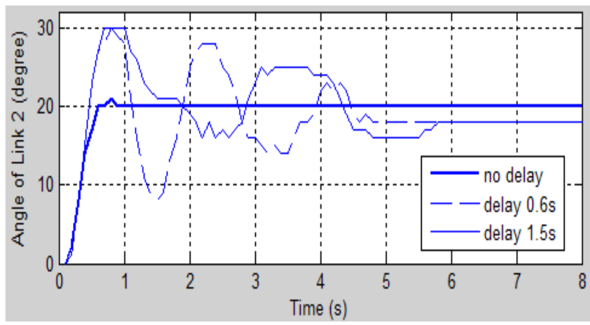


Fig. 15: Angle of link 2 with PID controller with Smith predictor.

IV. CONCLUSION

From the experimental results, we find that with common PID controller, the greater of system delay, the less effective of the control action because of longer rise-time, higher overshoot and bigger state error (Fig. 12 and Fig. 13). If delay time increase to a certain level (approximately 1 second), system will not stable with PID controller. But with the delay time up to 1.5 second, system is still well controlled by PID controller with Smith predictor, control quality is a little influenced (Fig. 14 and Fig. 15).

In summary, this paper presents how to apply neural network in object recognition and in two-link robot arm control using Smith predictor. The experimental results show that using Smith predictor applied neural network for any controller (PID controller in this case) ensure the anti-lag and control ability of the system even if feedback signal is significantly delayed.

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