

Double improved integral adaptive control of one order system

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Keywords: adaptive control, parameter identification, one order system

Abstract. In order to achieve adaptive control and single parameter identification of one order system, an ordinary adaptive control method is used in this paper. By introducing integral control and considering multiple variables, an adaptive control law is designed, and the result of parameter identification is analyzed. In the end, a conclusion can be made that theoretical analysis is correct and parameter identification method is effective by numerical simulation.

Introduction

Integral control is an classic control strategy and it is use in most control system to reduce system error^[1-7]. As the demand for control performance increases, the problem of time-variance parameters of controlled system is more and more important. A lot of parameter identification method is proposed by specialists and representatives from China and abroad. The classical parameter identification method is least square method^[1], Kalman filtering method, adaptive. The method modern parameter identification method is neural network method^[2], genetic algorithm method^[3] and particle swarm optimization. But calculating amount of these method is large, instantaneity and astringency can't meet the demands of the control system. In this paper, a double improved integral adaptive control^[8-11] is proposed, the simulation results show that system parameters can be identified.

Problem Description

One order system can be written as:

$$\dot{x} = ax + u \quad (1)$$

where a is unknown constant parameter, the goal is designing a controller such that the system state x can trace the expected value x^d .

Design Double Improved Integral Adaptive Identification Controller

An ordinary adaptive control method is used as follows, define a error variable as $z_1 = x_1 - x_1^d$, then

$$\dot{z}_1 = \dot{x}_1 - \dot{x}_1^d = ax + u \quad (2)$$

Design state feedback control law as:

$$u = -\hat{a}x - \sum_{i=1}^n k_i f_i(z_1) - k_{s1} \int z_1 dt \quad (3)$$

Choose $n = 1$, $k_i > 0$, $f_1(z_1) = z_1$. design regulating law:

$$\dot{\hat{a}} = \Gamma_a z_1 x \quad (4)$$

Define $z_2 = \int z_1 dt$, $\tilde{a} = a - \hat{a}$, then:

$$\begin{aligned}
\dot{z}_1 &= \tilde{a}x - k_{s_1}z_2 - k_1z_1 \\
\dot{z}_2 &= z_1 \\
\dot{\tilde{a}} &= -\Gamma_a z_1 x
\end{aligned} \tag{5}$$

choose Lyapunov function:

$$V = \frac{1}{2}z_1^2 + \frac{k_{s_1}}{2}z_2^2 + \frac{1}{2\Gamma_a}\tilde{a}^2 \tag{6}$$

Then:

$$\dot{V} = \tilde{a}xz_1 - k_1z_1^2 - k_{s_1}z_2z_1 + k_{s_1}z_2z_1 + \frac{1}{\Gamma_a}\tilde{a}\dot{\tilde{a}} = -k_1z_1^2 \leq 0 \tag{7}$$

The system is stable, and there is $z_1 \rightarrow 0$, but it can't make sure that system parameters can be identified.

The above model can be written as:

$$\begin{bmatrix} \dot{z}_1 \\ \dot{z}_2 \\ \dot{\tilde{a}} \end{bmatrix} = \begin{bmatrix} -k_1 & -k_{s_1} & x \\ 1 & 0 & 0 \\ -\Gamma_a x & 0 & 0 \end{bmatrix} \begin{bmatrix} z_1 \\ z_2 \\ \tilde{a} \end{bmatrix} \tag{8}$$

Obviously, system can make sure all state identified. Define:

$$\dot{z}_2 = z_1 - k_2z_2 \tag{9}$$

Then:

$$\begin{bmatrix} \dot{z}_1 \\ \dot{z}_2 \\ \dot{\tilde{a}} \end{bmatrix} = \begin{bmatrix} -k_1 & -k_{s_1} & x \\ 1 & -k_2 & 0 \\ -\Gamma_a x & 0 & 0 \end{bmatrix} \begin{bmatrix} z_1 \\ z_2 \\ \tilde{a} \end{bmatrix} \tag{10}$$

There is $z_1 \rightarrow 0, z_2 \rightarrow 0$, then

$$\dot{z}_1 = \tilde{a}x - k_{s_1}z_2 - k_1z_1 = \tilde{a}x = 0 \tag{11}$$

When $x \neq 0$, unknown system parameters can be identified. That is $\tilde{a} = 0$.

Obviously, the improved integral adaptive identification controller can ensure the system parameters be identified. Considering the third variable, then design:

$$\dot{\hat{a}} = \Gamma_a z_1 x - k_{ad1}\hat{a} \tag{12}$$

Then:

$$\dot{\tilde{a}} = -\dot{\hat{a}} = -\Gamma_a z_1 x + k_{ad1}\hat{a} = -\Gamma_a z_1 x + k_{ad1}(a - \tilde{a}) \tag{13}$$

Then:

$$\begin{bmatrix} \dot{z}_1 \\ \dot{z}_2 \\ \dot{\tilde{a}} \end{bmatrix} = \begin{bmatrix} -k_1 & -k_{s_1} & x \\ 1 & -k_2 & 0 \\ -\Gamma_a x & 0 & -k_{ad1} \end{bmatrix} \begin{bmatrix} z_1 \\ z_2 \\ \tilde{a} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ k_{ad1}a \end{bmatrix} \tag{14}$$

The balance point of system is:

$$\begin{bmatrix} z_1 \\ z_2 \\ \tilde{a} \end{bmatrix} = \begin{bmatrix} -k_1 & -k_{s_1} & x \\ 1 & -k_2 & 0 \\ -\Gamma_a x & 0 & -k_{ad1} \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ k_{ad1}a \end{bmatrix} \neq \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \tag{15}$$

It can't ensure system converge to zero.

Define that a is the forth state of system, then:

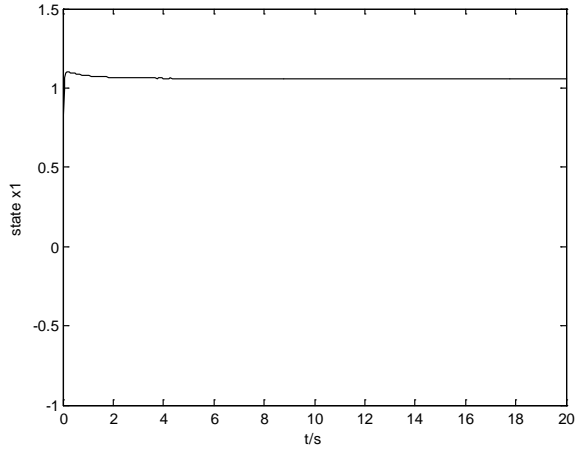


Fig.4 state a

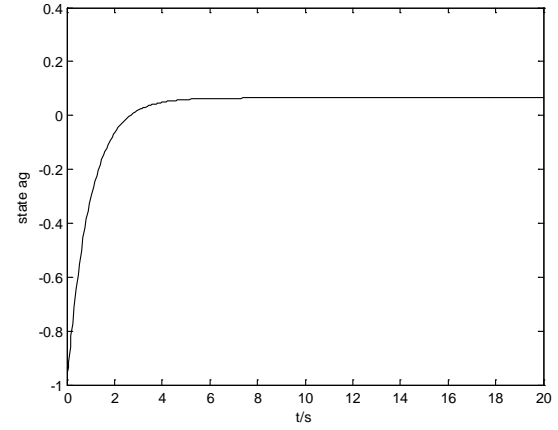


Fig.5 state x1

Choose $k_1 = 50$, $k_{s1} = 0$, $\Gamma_a = 1$, $k_2 = 1$, $k_{ad1} = 0$, the simulation results are as follows:

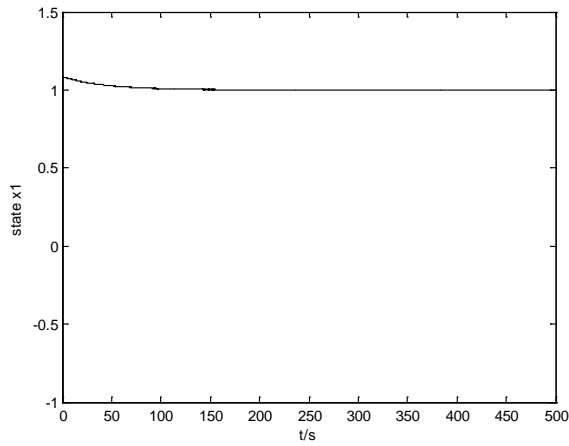


Fig.6 state a

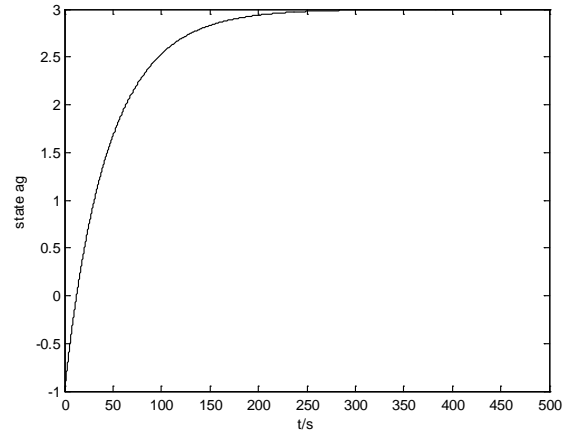


Fig.7 state x1

Choose $k_1 = 5$, $k_{s1} = 0$, $\Gamma_a = 1$, $k_2 = 1$, $k_{ad1} = 0$, the simulation results are as follows:

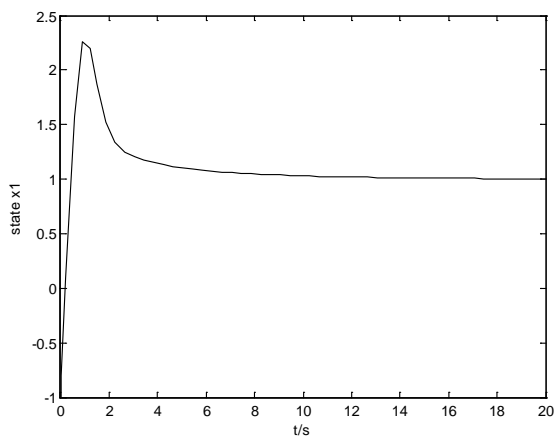


Fig.8 state a

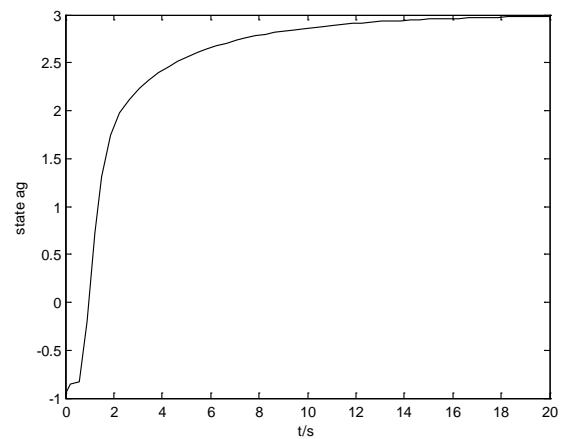


Fig.9 state x1

The convergence time is 20s. The result shows that if control error converge quickly, it will go against parameter identification. If control gain is small, the unknown parameter can be identified quickly.

Conclusion

According to the problem that system parameter need to be identified, a double improved integral adaptive control is proposed in this paper. By analysing theory and the simulation results, we can make a conclusion that the improved integral adaptive control method is effective to parameter identification. But if the control gain is too large, it will go against parameter identification.

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