

Integral Adaptive Control And Single Parameter Identification Based On Terminal Attractor And Sigmoid Function

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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. Integral control, Terminal attractor and Sigmoid function is combined to achieve parameter identification. Based on Laypunov method, an adaptive control law is designed to make the system insensitive to parameter uncertainties. In the end, a conclusion can be made that theoretical analysis is correct and parameter identification method is effective by numerical simulation.

Introduction

Adaptive control has been researched more and more in recent years by scientists in every country because of its strong ability to cope uncertain parameters in system model^[1-6]. As the demand for control performance increases, the problem of time-variance parameters of controlled system is more and more important. Terminal control has robustness and is not sensitive to parameter variation. Sigmoid function is one of the most transfer function in artificial neural networks, it is used in artificial neural networks^[7-9] at the earliest, it has continuity, smooth, differentiability, boundedness. In this paper, an improved integral adaptive control that is based on Terminal attractor and Sigmoid function 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 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 $n = 5, k_i > 0$

$$f_1(z_1) = z_1, \quad f_2(z_1) = z_1^3, \quad f_3(z_1) = z_1^{1/3} \quad (4)$$

$$f_4(z_1) = \frac{z_1}{|z_1| + \varepsilon}, \quad \varepsilon = 0.2, \quad (5)$$

$$f_5(z_1) = \frac{1 - e^{-\tau z_1}}{1 + e^{-\tau z_1}}, \quad \tau = 0.5 \quad (6)$$

where $f_3(z_1)$ is Terminal attractor, and $f_5(z_1)$ is Sigmoid function, $f_4(z_1)$ and $f_5(z_1)$ both have boundedness, Obviously, $f_i(z_1)$ meet $z_1 f_i(z_1) \geq 0$, then

$$\dot{z}_1 = \tilde{a}x - \sum_{i=1}^n k_i f_i(z_1) - k_{s1} \int z_1 dt \quad (7)$$

where the error variable \tilde{a} can be defined as:

$$\tilde{a} = a - \hat{a}, \quad (8)$$

design regulating law:

$$\dot{\hat{a}} = \Gamma z_1 x \quad (9)$$

where \hat{a} is unknown estimated parameter value, choose initial value $\hat{a}(0) = 0$, then

$$\dot{\tilde{a}} = -\dot{\hat{a}} \quad (10)$$

choose Lyapunov function:

$$V = \frac{1}{2} z_1^2 + \frac{1}{2\Gamma} \tilde{a}^2 + \frac{k_{s1}}{2} \left(\int z_1 dt \right)^2 \quad (11)$$

Then

$$\dot{V} = z_1 \dot{z}_1 + \frac{1}{\Gamma} \tilde{a} \dot{\tilde{a}} + k_{s1} z_1 \int z_1 dt \quad (12)$$

Then:

$$\dot{V} = z_1 \tilde{a}x - \sum_{i=1}^n k_i z_1 f_i(z_1) - \frac{1}{\Gamma} \tilde{a} \Gamma z_1 x = - \sum_{i=1}^n k_i z_1 f_i(z_1) \leq 0 \quad (13)$$

So $z_1 \rightarrow 0$.

Parameter Identification Result Analysis

When $z_1 \rightarrow 0$, where $u = -\hat{a}x$, then

$$\dot{z}_1 = ax - \hat{a}x + k_{s1} \int z_1 dt = \tilde{a}x + k_{s1} \int z_1 dt \quad (14)$$

When $z_1 \rightarrow 0$, there is $\dot{z}_1 \rightarrow 0$, then there is $\dot{z}_1 = \tilde{a}x + k_{s1} \int z_1 dt = 0$, so the parameter can be identified.

Obviously, if there is an integral adaptive control, the parameter can be identified.

Numerical Simulation

Choose $a = 3$, $x_1^d = 2$, $x_1(0) = -1$, use Simulink in Matlab, the program can be written as:

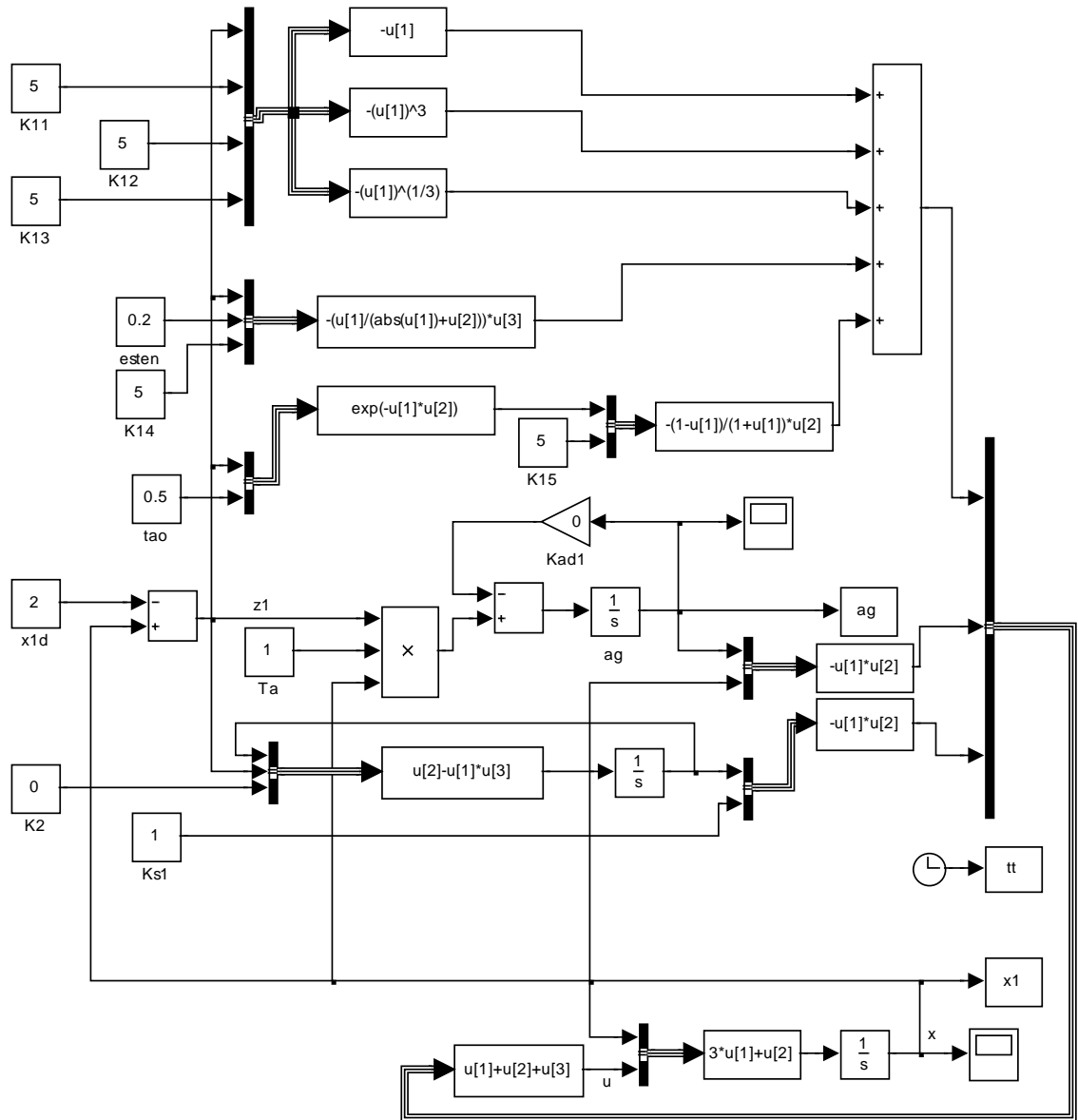


Fig.1 Program

Choose $k_1 = 5$, $k_{s1} = 1$, $\Gamma_a = 1$, $k_2 = k_3 = k_4 = k_5 = 5$, $k_{ad1} = 0$, $\tau = 0.5$, $\varepsilon = 0.2$, the simulation results are as follows:

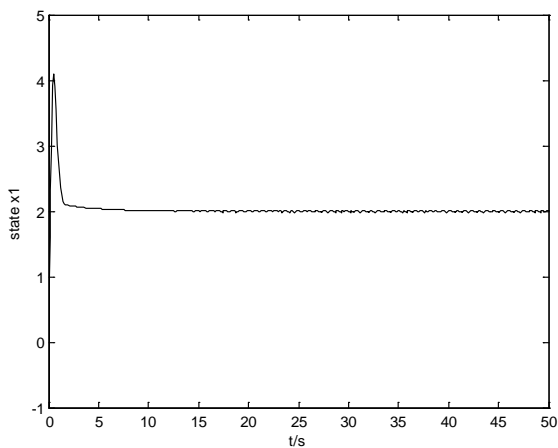


Fig.2 state x

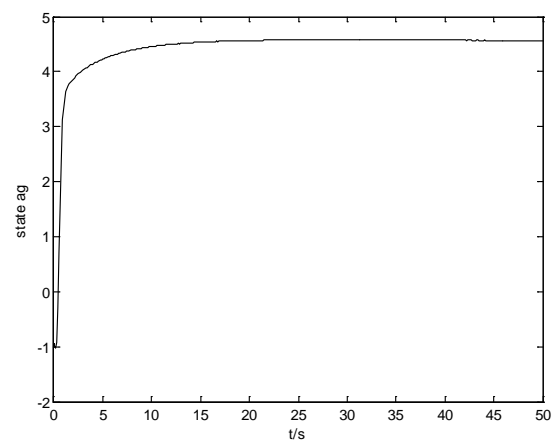


fig.3 state a

The simulation results show that the error of system is small, but the error of parameter

identification is large, the main reason is that there is a nonlinear function.

Consider decreasing system shock, that is $k_4 = 0.2$, $\varepsilon = 2$, the simulation results are as follows:

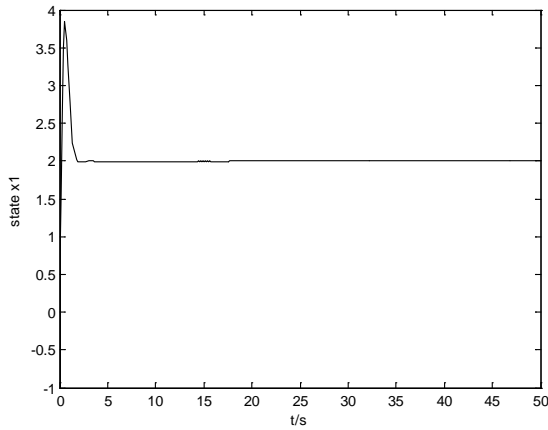


Fig.4 state x

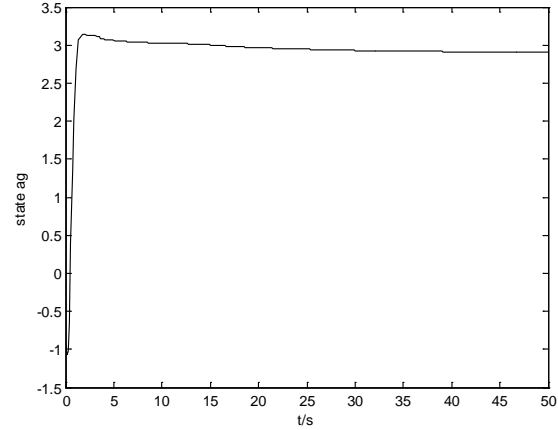


fig.5 state a

The simulation results show that the error of system is small, and the error of parameter identification is small. This one of advantage of nonlinear function, but the disadvantage is to use variable step emulation. Because Terminal function and Sigmoid function is used, it make the effect of integral decrease. So effect to the error of parameter identification decrease, integral of error as follows:

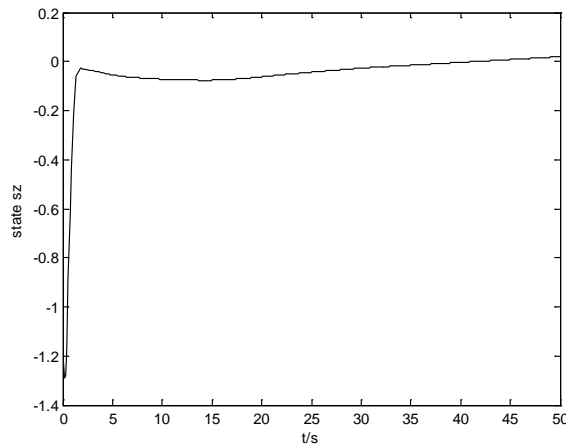


Fig.6 integral of error

Conclusion

Terminal function and Sigmoid function can decrease control parameter, it make the effect of integral decrease, and it make steady state error decrease. But the disadvantage is that variable step emulation must be used, because fixed step can not use nonlinear function's the characteristic of variable gain.

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