Research on parameters identification of system with uncertainty and unknown parameter

Guangbin Wu[1,a] , Guoqiang Liang[1], and Junwei Lei[1, b]

[1]Department of control engineering, Naval aeronautical and astronautical University, Yantai, China

[a]wuguangbin1024@126.com, [b]leijunwei@126.com

Key words: adaptive control, parameter identification, one order system, stability

Abstract: In order to illustrate the complexity of system parameter identification, this paper takes a simple one order system as an example, which contains an unknown parameter and an uncertain term. It adopts the adaptive method to design the identification rules of unknown parameters, and uses the robust control method to deal with the uncertainty. And system stability is proved by constructing a Lyapunov function. The simulation results show that the stability control of the system is simple, but it is not possible to accurately identify the parameters of the system in the presence of uncertainty.

1. Introduction

The parameter identification problem has been widely studied in recent years, and many methods have been proposed, and good results have been achieved. Since it is very convenient to construct Lyapunov function to prove the stability of system, the adaptive control and parameter identification method is one of most favorite method of most researchers[1-4]. But the problem of parameter identification is more complex, and it is more difficult to identify the parameter in many cases than the stability of the system. And the parameter identification problem is more difficult in the case of system with uncertainties[6-11]. The main purpose of this paper is to show that the parameters can not be fully identified in the presence of uncertainty. In spite of a simple class of first order systems with unknown parameters and uncertainties was taken as an example, the design, derivation and simulation of this paper are sufficient to show the above conclusions. Therefore, in view of the uncertain system, we can design the control law to make it stable, but it is difficult to use the adaptive method to get the accurate identification of the parameters.

2. Problem description

One order system can be written as：

$$\dot{x} = a_1 x + u + \Delta(x,t) \qquad \text{（Eq.1）}$$

where a_1 is unknown constant parameter, $\Delta(x,t)$ is system uncertainty, and it can be chosen as $\Delta(x,t) = a_2 \sin x$, the goal is designing a controller $u = h(x, \hat{a}_1)$ such that the system state x can trace the expected value x^d and $\hat{a}_1$ can converged to a_1 .

3. Design of 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

$$\dot{z}_1 = \dot{x}_1 - \dot{x}_1^d = a_1 x + a_2 \sin x + u \qquad \text{(Eq.2)}$$

Design state feedback control law as:

$$u = -\hat{a}_1 x - \sum_{i=1}^{n} k_i f_i(z_1) \qquad \text{(Eq.3)}$$

Choose $n = 5$, $k_i > 0$

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

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

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

where $f_3(z_1)$ is Terminal attractor, and $f_5(z_1)$ is Sigmoid function, $f_4(z_1)$ and $f_5(z_1)$ are both bounded, Obviously, $f_i(z_1)$ satisfies $z_1 f_i(z_1) \geq 0$, then

$$\dot{z}_1 = \tilde{a}_1 x - \sum_{i=1}^{n} k_i f_i(z_1) \qquad \text{(Eq.7)}$$

where the error variable $\tilde{a}_1$ can be defined as:

$$\tilde{a}_1 = a_1 - \hat{a}_1 \qquad \text{(Eq.8)}$$

Design regulating law as:

$$\dot{\hat{a}}_1 = \Gamma_1 z_1 x \qquad \text{(Eq.9)}$$

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

$$\dot{\tilde{a}}_1 = -\dot{\hat{a}}_1 \qquad \text{(Eq.10)}$$

Choose a Lyapunov function as:

$$V = \frac{1}{2} z_1^2 + \frac{1}{2\Gamma_1} \tilde{a}_1^{\,2} \qquad \text{(Eq.11)}$$

Then

$$\dot{V} = z_1 \dot{z}_1 + \frac{1}{\Gamma_1} \tilde{a}_1 \dot{\tilde{a}}_1 \qquad \text{(Eq.12)}$$

Then:

$$\dot{V} = z_1\tilde{a}_1 x + z_1 a_2 \sin x - \sum_{i=1}^{n} k_i z_1 f_i(z_1) - \frac{1}{\Gamma_1}\tilde{a}_1\Gamma_1 z_1 x$$
$$= -\sum_{i=1}^{n} k_i z_1 f_i(z_1) + z_1 a_2 \sin x \le 0 \qquad \text{(Eq.12)}$$

According to Lyapunov theory, we get $z_1 \to 0$.

4. Parameter identification result analysis

When $z_1 \to 0$, where $u = -\hat{a}_1 x$, then

$$\dot{z}_1 = a_1 x - \hat{a}_1 x + a_2 \sin x = \tilde{a}_1 x + a_2 \sin x \qquad \text{(Eq.13)}$$

When $z_1 \to 0$, there is $\dot{z}_1 \to 0$, then there is $\dot{z}_1 = \tilde{a}_1 x + a_2 \sin x = 0$, so the parameter can not be identified.

5. Numerical simulation

Choose unknown parameter $a_1 = 3$ and $a_2 = 3$, set expected value as $x_1^d = 1$ and initial state $x_1(0) = -1$, write matlab m language program as follows:

```
clc;clear; k11=-10;k12=-5;k13=-5;k14=-5;k15=-5;k16=-5;esten1=0.2;taox=3;
```

Construct a Simulink program with Matlab software as follows:

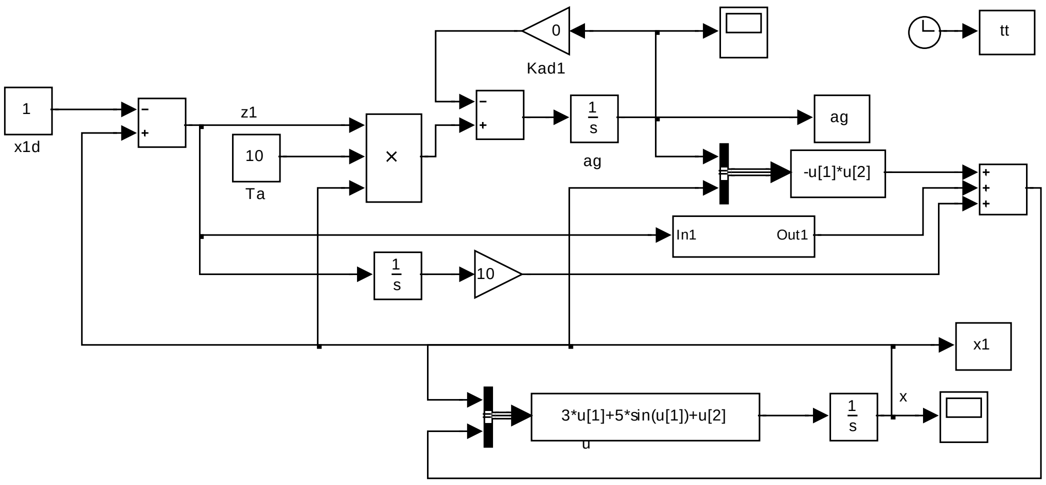

Fig.1 Program structure with simulink

Use following program to plot simulation figures:

```
figure(1);plot(tt,xx,'k');xlabel('t/s');ylabel('state x1');
figure(2);plot(tt,a1g,'k');xlabel('t/s');ylabel('state a1g');
```

Choose the speed of adaptive law as $\Gamma_1 = 10$, the simulation results are as follows:

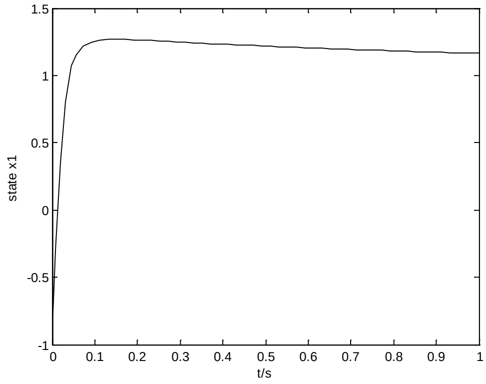

Fig.2 state x1

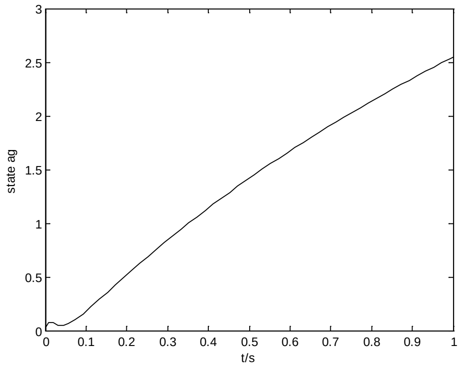

Fig.3 state ag

According to the above simulation result, the error can converge to zero, but unknown parameter can not be identified.

Choose the speed of adaptive law as $\Gamma_1 = 0$, the simulation results are as follows:

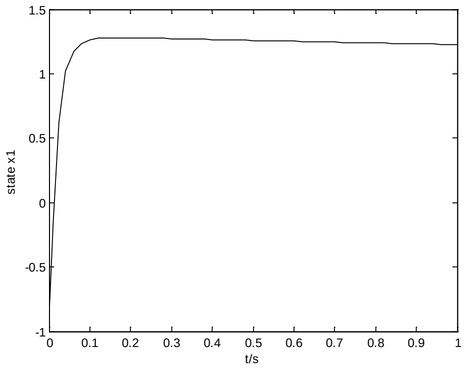

Fig.4 state a

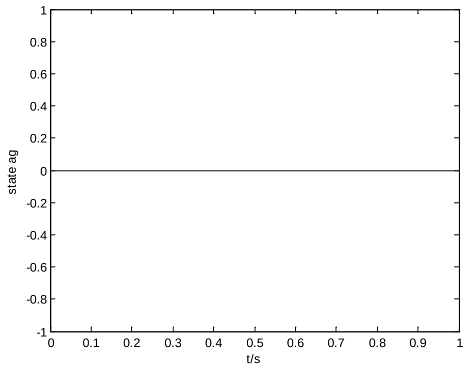

Fig.5 state x1

The unknown parameter can not be identified. So we increase the adaptive law speed as $\Gamma_1 = 10000$ and the simulation result is as follows:

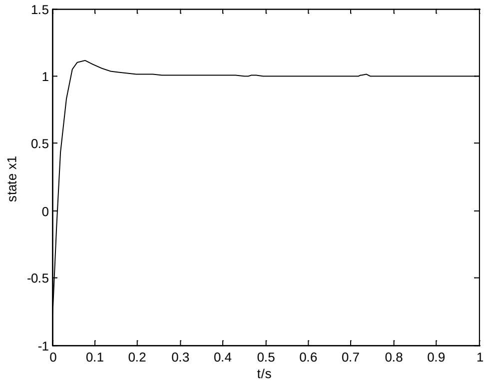

Fig.6 state a

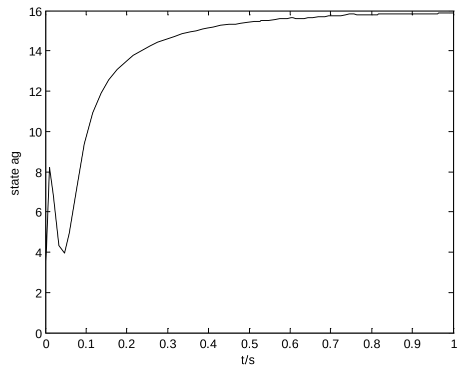

Fig.7 state x1

The simulation results show that no matter how big the adaptive law gain is chosen, the unknown parameter is always can not be identified. But if the gain is chosen too big, the system will be even unstable .

6. Conclusion

In this paper, a simple first-order system with an unknown parameter and an uncertain unknown function was taken as an example. By using the method of combining the adaptive law and the Lyapunov function to design the system stability control law, the stability of the system is proved. Finally detailed numerical simulation analysis shows that, even for a simple first-order uncertainty system, parameter identification is almost impossible. and for the high nonlinear uncertainty system, the difficulty is beyond doubt. Therefore, it is suggested that the main research should be considered to solve the stability problem of the uncertain system, and it is not recommended to spend too much energy on the identification of unknown parameters.

referenceS

[1]Mooij E and Barkana I，Stability Analysis of an Adaptive Guidance and Control System applied to a Winged Re-entry Vehicle，Proceedings of the 2005 AIAA Guidance，Navigation，and ControI Conference and Exhibit,San Francisco，CA，AIAA 2005:6290

[2]S. Juliana, Q. P. Chu, J. A. Mulder, T. J. van Baten, Flight control of atmospheric re-entry vehicle with non-linear dynamic inversion [A], In: AIAA Guidance, Navigation, and Control Conference and Exhibit [C], Providence: AIAA, 2004-5330

[3]Johnson MD, Calise AJ, and Johnson EN, Evaluation of an Adaptive Method for Launch Vehicle Flight Control [A], In: AIAA Guidance, Navigation and Control Conference[C], Austin: AIAA, 2003: 1-11.

[4]Johnson MD, Calise AJ, and Johnson EN, Further Evaluation of an Adaptive Method for Launch Vehicle Flight Control [A], In: AIAA Guidance, Navigation and Control Conference [C], Providence: AIAA, 2004: 1-17.

[5]Baohua Lian, Hyochoong Bang, J. E. Hurtado, Adaptive Backstepping control based autopilot design for reentry vehicle [A], In: AIAA Guidance, Navigation, and Control Conference and Exhibit [C], Providence: AIAA, 2004-5328

[6]J. Fatemi, E. Mooij, S. P. Gurav, Reentry vehicle design optimization with intergrated trajectory uncertainties [A], In: AIAA 13th International Space Planes and Hypersonic Systems and Technologies Conference [C], AIAA, 2005-3386

[7] Azinheira J R, Moutinho A, Paiva E C. A backstepping controller for path-tracking of an underactuated autonomous aitship.[J] International Journal of Robust and Nonlinear Control, 2009, 19(4):418-441

[8] Benjovengo F P, Paiva E C. Sliding mode control approaches for an autonomous unmanned airship. AIAA 2009-2869, 2009

[9] Park, C.S., H.Lee, M.J.Tahk, et al. Airship control using neural network augmented model inversion[J]. IEEE Conference on Control Applications. 2003

[10] Xie, S.R., J.Luo, J.J.Rao, et al. Computer Vision-based Navigation and Predefined Track Following Control of a Small Robotic Ariship. 2007.33(3):286-291.

[11] Rao, J., Z.Gong, J.Luo, et al., Robotics airship mission path-following control based on ANN and human operator’s skill. 2007.29:5-15.