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Simultaneous Stabilization for Singularly Perturbed Systems via Iterative Linear Matrix Inequalities[1)]

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Abstract This paper investigates simultaneous stabilization of several linear singularly perturbed systems using a single linear state feedback controller. Simultaneous stability conditions for the singularly perturbed systems are derived and represented in terms of a set of matrix inequalities, and the stiff problem is avoided since the design procedure is independent of the small parameter. By the proposed two-stage procedure, the stable simultaneous feedback gains and Lyapunov functions can be found. The outcome of the simultaneous stabilization problem is recast into a set of bilinear matrix inequalities (BMIs) in each stage. The resulting BMIs can be effectively solved by the proposed iterative linear matrix inequality (ILMI) approach. The convergence of the algorithms is also investigated. The algorithms can be used for both standard and nonstandard singularly perturbed systems. Furthermore, numerical examples and simulation results are given to verify the effectiveness of the algorithms.

Key words Singular perturbation, linear matrix inequalities, simultaneous stabilization

1 Introduction

Many plants involve physical and chemical phenomena of different time scales, such as complex circuits, flexible-joint manipulators, flexible-link robots, communication networks, *etc*. The resulting stiff problem makes the analysis and synthesis very difficult. Fortunately, singular perturbation theory is proven to be a successful analytic tool for modeling, analysis and synthesis of well-conditioned controllers for multiple time-scale plants. By this method, slow and fast variables can be separated explicitly due to the small perturbed parameter, and the controllers can be designed according to different time scales to avoid the stiff problem. For more details on recent development of application and techniques of singular perturbation in control, see [1,2] and the references therein.

The feedback control of linear singularly perturbed system has been extensively studied in the literature via the slow-fast decomposition method. Loosely speaking, the research approaches can be divided into two categories, one is so-called classical decomposition, where the slow subsystem is viewed as a regular state-space form, but the nonstandard singularly system is difficult to dealt with. The other is descriptor system approach[3,4], which is suitable for both standard and nonstandard singularly perturbed systems. Forall of the above mentioned methods, the Riccati equation is utilized as the main solver and the famous implicit function theorem acts as the theoretic basis. As an alternative to Riccati equation, linear matrix inequalities (LMIs)[5] have emerged as a powerful formulation and design technique for a variety of singularly perturbed control problems[6~8].

On the other hand, simultaneous stabilization is an important problem in the area of

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robust control design. Simultaneous stabilization via state feedback control has been studied, such as in [9]. Recently, [10] proposed an iterative LMIs (ILMIs) approach to realize the simultaneous stabilization via static output feedback. However, there is no related result about singularly perturbed systems.

2 Simultaneous stabilization for linear singularly perturbed systems

Consider r singularly perturbed plants G^i

$$G^i:\ \begin{cases}\dot{x} = A_{11}^i x + A_{12}^i z + B_1^i u, & x(0) = x_0\\ \varepsilon\dot{z} = A_{21}^i x + A_{22}^i z + B_2^i u, & z(0) = z_0\end{cases}\quad i = 1, 2, \cdots, r \tag{1}$$

where $x(t)\in R^n$, $z(t)\in R^m$, $u(t)\in R^p$, $A_{11}^i, A_{12}^i, A_{21}^i, A_{22}^i, B_1^i, B_2^i$ are constant matrices of appropriate dimensions. The problem we need address in this section is to design a single linear state feedback control law $u=K_1x+K_2z$ to make the r closed-loop singularly perturbed systems G_c^i

$$G_c^i:\ \begin{cases}\dot{x} = (A_{11}^i + B_1^i K_1)x + (A_{12}^i + B_1^i K_2)z\\ \varepsilon\dot{z} = (A_{21}^i + B_2^i K_1)x + (A_{22}^i + B_2^i K_2)z\end{cases}\quad i = 1, 2, \cdots, r \tag{2}$$

simultaneously stabilized.

Theorem 1. If there exist matrices P^i, K_1 and K_2 with compatible dimensions satisfying the matrix inequalities:

$$P_s^i = \begin{bmatrix} P_{11}^i & 0\\ P_{21}^i & P_{22}^i\end{bmatrix}, \text{where } P_{11}^i = (P_{11}^i)^{\mathrm{T}} > 0, P_{22}^i = (P_{22}^i)^{\mathrm{T}} > 0 \tag{3}$$

$$\Pi^i = \begin{bmatrix}\Sigma^i & \Delta^i\\ * & \Xi^i\end{bmatrix} < 0,\quad i = 1, 2, \cdots, r \tag{4}$$

where

$$\Sigma^i = (A_{11}^i + B_1^i K_1)^{\mathrm{T}} P_{11}^i + P_{11}^i (A_{11}^i + B_1^i K_1) + (A_{21}^i + B_2^i K_1)^{\mathrm{T}} P_{21}^i + (P_{21}^i)^{\mathrm{T}} (A_{21}^i + B_2^i K_1)$$
$$\Delta^i = (A_{21}^i + B_2^i K_1)^{\mathrm{T}} P_{22}^i + P_{11}^i (A_{12}^i + B_1^i K_2) + (P_{21}^i)^{\mathrm{T}} (A_{22}^i + B_2^i K_2)$$
$$\Xi^i = (A_{22}^i + B_2^i K_2)^{\mathrm{T}} P_{22}^i + (P_{22}^i)^{\mathrm{T}} (A_{22}^i + B_2^i K_2)$$

then $\exists\,\varepsilon^*$, $\forall\,\varepsilon\in(0,\varepsilon^*]$, the controller

$$u = K_1 x + K_2 z \tag{5}$$

can make the r closed-loop systems G_c^i stabilized.

Proof. For $G_c^i (i=1, 2, \cdots, r)$, let $P_\varepsilon^i = \begin{bmatrix} P_{11}^i & \varepsilon(P_{21}^i)^{\mathrm{T}}\\ P_{21}^i & P_{22}^i\end{bmatrix}$. Since $P_{11}^i = (P_{11}^i)^{\mathrm{T}} > 0$ and $P_{22}^i = (P_{22}^i)^{\mathrm{T}} > 0$, $\exists\,\varepsilon_0 > 0$, $\forall\,\varepsilon\in(0,\varepsilon_0]$

$$E_\varepsilon P_\varepsilon^i = (P_\varepsilon^i)^{\mathrm{T}} E_\varepsilon = \begin{bmatrix} P_{11}^i & \varepsilon(P_{21}^i)^{\mathrm{T}}\\ \varepsilon P_{21}^i & \varepsilon P_{22}^i\end{bmatrix} > 0, \text{where } E_\varepsilon = \begin{bmatrix} I_{n\times n} & \\ & \varepsilon\cdot I_{m\times m}\end{bmatrix}.$$

So these r Lyapunov functions can be defined as $V^i = \boldsymbol{\theta}^{\mathrm{T}} E_\varepsilon P_\varepsilon^i \boldsymbol{\theta}$, where $\boldsymbol{\theta}^{\mathrm{T}} = [x, z]$. Thus,

$$\frac{\mathrm{d}}{\mathrm{d}t} V^i(\boldsymbol{\theta}) = \boldsymbol{\theta}^{\mathrm{T}} E_\varepsilon P_\varepsilon^i \dot{\boldsymbol{\theta}} + \dot{\boldsymbol{\theta}}^{\mathrm{T}} (P_\varepsilon^i)^{\mathrm{T}} E_\varepsilon \boldsymbol{\theta} = [\dot{x}^{\mathrm{T}}\quad \varepsilon\dot{z}^{\mathrm{T}}] P_\varepsilon^i \begin{bmatrix} x\\ z\end{bmatrix} + [x^{\mathrm{T}}\quad z^{\mathrm{T}}] (P_\varepsilon^i)^{\mathrm{T}} \begin{bmatrix}\dot{x}\\ \varepsilon\dot{z}\end{bmatrix}$$
$$= [x^{\mathrm{T}}\quad z^{\mathrm{T}}]\cdot \Pi_\varepsilon^i \cdot \begin{bmatrix} x\\ z\end{bmatrix}$$

where $\Pi_\varepsilon^i = \begin{bmatrix}\Sigma_\varepsilon^i & \Delta_\varepsilon^i\\ * & \Xi_\varepsilon^i\end{bmatrix}$

$$\Sigma_\varepsilon^i = (A_{11}^i + B_1^i K_1)^{\mathrm{T}} P_{11}^i + P_{11}^i (A_{11}^i + B_1^i K_1) + (A_{21}^i + B_2^i K_1)^{\mathrm{T}} P_{21}^i + (P_{21}^i)^{\mathrm{T}} (A_{21}^i + B_2^i K_1)$$
$$\Delta_\varepsilon^i = (A_{21}^i + B_2^i K_1)^{\mathrm{T}} P_{22}^i + P_{11}^i (A_{12}^i + B_1^i K_2) + (P_{21}^i)^{\mathrm{T}} (A_{22}^i + B_2^i K_2) + \varepsilon\,(A_{11} + B_1 K_1)^{\mathrm{T}} (P_{21}^i)^{\mathrm{T}}$$
$$\Xi_\varepsilon^i = (A_{22}^i + B_2^i K_2)^{\mathrm{T}} P_{22}^i + P_{22}^i (A_{22}^i + B_2^i K_2) + \varepsilon (A_{12}^i + B_1^i K_2)^{\mathrm{T}} (P_{21}^i)^{\mathrm{T}} + \varepsilon P_{21}^i (A_{12}^i + B_2^i K_2)$$

It is obvious that $\Pi_\varepsilon^i = \Pi^i + \begin{bmatrix} 0 & O(\varepsilon)\\ O(\varepsilon) & O(\varepsilon)\end{bmatrix} = \Pi^i + O(\varepsilon)$

Since $\Pi^i<0$, for plant i, $\exists\,\varepsilon_i^*>0$, $\forall\,\varepsilon\in(0,\varepsilon_i^*]$, the closed-loop system G_c^i is stable. If $\bar{\varepsilon}=\min\limits_i(\varepsilon_i^*)$ and $\varepsilon^*=\min\{\varepsilon_0,\bar{\varepsilon}\}$, then for $\varepsilon\in(0,\varepsilon^*]$, these r closed-loop systems remain stable. □

3 ILMI algorithms

Generally speaking, (3)~(4) is a nonlinear matrix inequalities, and directly solving (3)~(4) can not give any explicit results for the original singularly perturbed system (1)[11]. In the following, we will give a special kind of solution for (3)~(4), and the closed-loop stability will be proved.

First, from Schur complements, (3)~(4) imply

$$P_{22}^i=(P_{22}^i)^{\mathrm T}>0,\quad \Xi^i=(A_{22}+B_2K_2)^{\mathrm T}P_{22}^i+P_{22}^i(A_{22}+B_2K_2)<0 \tag{6}$$

So we can solve (6), then substitute the obtained P_{22}^i and K_2 into (3)~(4).

Solving the inequalities (6) need ILMI technology, which is based on the following theorem(the proof is similar to [12] so is omitted here).

Theorem 2. There exist matrices K_2 and P_{22}^i satisfying

$$P_{22}^i=(P_{22}^i)^{\mathrm T}>0,\quad (A_{22}^i+B_2^iK_2)^{\mathrm T}P_{22}^i+P_{22}^i(A_{22}^i+B_2^iK_2)<0,\ i=1,2,\cdots,r \tag{7}$$

if and only if there exist matrices K_2 and $P_{22}^i, K_{20}, P_{220}^i$ satisfying

$$P_{22}^i=(P_{22}^i)^{\mathrm T}>0,\quad P_{220}^i=(P_{220}^i)^{\mathrm T}>0 \tag{8a}$$

$$\begin{bmatrix}\Theta^i & P_{22}^iB_2^i+(K_2)^{\mathrm T}\\ * & -I\end{bmatrix}<0,\quad i=1,2,\cdots,r \tag{8b}$$

where

$$\Theta^i=(A_{22}^i)^{\mathrm T}P_{22}^i+P_{22}^iA_{22}^i-P_{22}^iB_2^i(B_2^i)^{\mathrm T}P_{220}^i-P_{220}^iB_2^i(B_2^i)^{\mathrm T}P_{22}^i+P_{220}^iB_2^i(B_2^i)^{\mathrm T}P_{220}^i-K_2^{\mathrm T}K_{20}-K_{20}^{\mathrm T}K_2+K_{20}^{\mathrm T}K_{20} \tag{9}$$

Obviously, in (8), if P_{220}^i and K_{20}^i are fixed, then it becomes a set of LMIs with respect to P_{22}^i and K_2^i. To guarantee the feasibility, we can relax it as

$$\begin{bmatrix}\Theta^i-\alpha P_{22}^i & P_{22}^iB_2^i+(K_2)^{\mathrm T}\\ * & -I\end{bmatrix}<0 \tag{10}$$

So, the simultaneous stabilization for r fast subsystems can be solved via Algorithm 1 described below.

Algorithm 1.

Step 1. Initiation: select $Q_{22}^i>0$, solve the following r algebraic Riccati equations:

$$(A_{22}^i)^{\mathrm T}P_{220}^i+(P_{220}^i)^{\mathrm T}A_{22}^i-P_{220}^iB_2^i(B_2^i)^{\mathrm T}P_{220}^i+Q_{22}^i=0$$

and obtain the r initial value: $K_{20}^i=-B_2^iP_{220}^i$, arbitrarily select one of K_{20}^i as K_{20}.

Step 2. min α subject to: $P_{22}^i=(P_{22}^i)^{\mathrm T}>0$, and (10). Assume the optimal value is α'.

Step 3. If $\alpha'<0$, then P_{22}^i, K_{22} are feasible solutions. Stop.

Step 4. min $\sum_{i=1}^{r}trace(P_{22}^i)$ subject to: $P_{22}^i=(P_{22}^i)^{\mathrm T}>0$ and (10), where α is replaced by α'.

Step 5. If $\sum_{i=1}^{r}\|P_{22}^i-P_{220}^i\|>\delta_1$, where δ_1 is a pre-determined tolerance, then set $P_{220}^i=P_2^i$, $K_{20}=K_2$, $t=t+1$ and goto Step 2; else, the problem may not be solved by this approach, Stop.

In Step 2, substituting K_2 and P_{22}^i into (3)~(4), (3)~(4) are still not LMIs, so the ILMI approach will be adopted to solve it, which is based on the following theorem (the proof is similar to [12] so is omitted here).

Theorem 3. There exist P_{11}^i, P_{21}^i, K_1 satisfying

$$P_{11}^i=(P_{11}^i)^{\mathrm T}>0,\ \Pi^i<0 \tag{11}$$

If and only if there exist P_{11}^i, P_{21}^i, K_1, and $P_{110}^i, P_{210}^i, K_{10}$ satisfying

$$P_{11}^i = (P_{11}^i)^T > 0, \quad P_{110}^i = (P_{110}^i)^T > 0 \tag{12a}$$

$$\begin{bmatrix} \Omega^i & P_{11}^i B_1^i + K_1^T & (P_{21}^i)^T B_2^i + K_1^T & \Delta^i \\ * & -I & & \\ * & & -I & \\ * & & & \Xi^i \end{bmatrix} < 0 \tag{12b}$$

where

$$\Omega^i = (A_{11}^i)^T P_{11}^i + P_{11}^i A_{11}^i + (A_{21}^i)^T P_{21}^i + (P_{21}^i)^T A_{21}^i - P_{11}^i B_1^i (B_1^i)^T (P_{110}^i)^T - P_{110}^i B_1^i (B_1^i)^T P_{11}^i + P_{110}^i B_1^i (B_1^i)^T P_{110}^i - (P_{21}^i)^T B_2^i (B_2^i)^T P_{210}^i - (P_{210}^i)^T B_2^i (B_2^i)^T P_{21}^i + (P_{210}^i)^T B_2^i (B_2^i)^T P_{210}^i - 2K_1^T K_{10}^T - 2K_{10}^T K_1 + 2K_{10}^T K_{10} \tag{13}$$

Obviously, in (12), if P_{110}^i, P_{210}^i, and K_{10}^i are fixed, then it becomes a set of LMIs with respect to P_{11}^i, P_{21}^i, and K_1^i. To guarantee the feasibility, we can relax it as

$$\begin{bmatrix} \Omega^i - \alpha P_{11}^i & P_{11}^i B_1^i + K_1^T & (P_{21}^i)^T B_2^i + K_1^T & \Delta^i \\ * & -I & & \\ * & & -I & \\ * & & & \Xi^i \end{bmatrix} < 0 \tag{14}$$

So, the simultaneous stabilization for r slow subsystems can be solved via Algorithm 2 described below.

Algorithm 2.

Step 1. Initialization: Select $Q^i > 0$, solve the following r generalized Riccati equations

$$(A^i)^T P_0^i + (P_0^i)^T A^i - (P_0^i)^T B^i (B^i)^T P_0^i + Q^i = 0, \quad E^T P_0^i = (P_0^i)^T E$$

We can obtain P_{110}^i, P_{210}^i, K_{10}^i, and arbitrarily select one of K_{10}^i as K_{10} (See [4] for the details).

Step 2. min α subject to: $P_{11}^i = (P_{11}^i)^T > 0$ and (14). Assume the optimal value is α^t.

Step 3. If $\alpha^t < 0$, then P_{11}^i, P_{21}^i, K_1 are feasible solutions. Stop.

Step 4. min $\sum_{i=1}^{r} trace(P_{11}^i)$ subject to: $P_{11}^i = (P_{11}^i)^T > 0$ and (14) where α is replaced by α^t.

Step 5. If $\sum_{i=1}^{r} \| P_{11}^i - P_{110}^i \| > \delta_2$, where δ_2 is a pre-determined tolerance, then set $P_{110}^i = P_{11}^i$, $P_{210}^i = P_{21}^i$, $K_{10} = K_1$, $t = t+1$, and go to Step 2; else, the problem may not be solved by this approach. Stop.

Remark 1. From [10] we can see that the sequence $\{\alpha^t\}$ will be a non-increasing sequence.

Remark 2. It is obvious that the initial values can affect the convergence of these algorithms. Changing Q_f^i and Q^i can obtain different initial values.

4 Numerical examples

Example 1. Consider two singularly perturbed plants, which are described as

$$A_{11}^1 = \begin{bmatrix} -0.95 & -0.68 \\ 1.478 & 0 \end{bmatrix}, \quad A_{12}^1 = \begin{bmatrix} -0.92 & 0.11 \\ 0 & 0 \end{bmatrix}, \quad A_{21}^1 = \begin{bmatrix} 0.2 & 0.4 \\ 0.14 & 0.5 \end{bmatrix}$$

$$A_{22}^1 = \begin{bmatrix} 0.68 & 0.428 \\ -2.103 & -0.215 \end{bmatrix}, \quad B_1^1 = \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \quad B_2^1 = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$A_{11}^2 = \begin{bmatrix} -0.5 & -1.08 \\ 0.57 & 0.2 \end{bmatrix}, \quad A_{12}^2 = \begin{bmatrix} -0.22 & 0.14 \\ 0 & 0.3 \end{bmatrix}, \quad A_{21}^2 = \begin{bmatrix} 0.5 & 0.3 \\ 0.54 & 0.23 \end{bmatrix}$$

$$A_{22}^2 = \begin{bmatrix} 0.8 & 0.28 \\ 1.245 & -0.512 \end{bmatrix}, \quad B_1^2 = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, \quad B_2^2 = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

1) Initialization: select $Q^i = I_{4\times 4}, Q^i_{22} = I_{2\times 2}, \delta_1 = \delta_2 = 10^{-4}$.

2) By using Algorithm 1, after only one iteration, a feasible solution can be found: $\alpha = -1.5362$

$$P^1_{22} = \begin{bmatrix} 137.2783 & 14.5751 \\ 14.5751 & 2.7520 \end{bmatrix},\ P^2_{22} = \begin{bmatrix} 82.1477 & 13.5164 \\ 13.5164 & 2.3525 \end{bmatrix},\ K_2 = [-28.5599 \quad -5.0522]$$

3) By using Algorithm 2, after 17 iterations, a feasible solution can be found: $\alpha = -0.0060$

$$P^1_{11} = \begin{bmatrix} 515.8354 & 39.4610 \\ 39.4610 & 333.4700 \end{bmatrix},\quad P^1_{21} = \begin{bmatrix} -333.7649 & -34.1066 \\ -7.8010 & -0.0209 \end{bmatrix}$$

$$P^1_{11} = \begin{bmatrix} 2.2877 & -0.3651 \\ -0.3651 & 2.7298 \end{bmatrix},\quad P^1_{21} = \begin{bmatrix} 32.4050 & -17.6205 \\ 5.9227 & -2.1893 \end{bmatrix}$$

$$K_1 = [-11.7424 \quad -1.8237]$$

The evolving history of optimal α is depicted in Fig. 1, where the abscissa represents the number of iterations, vertical coordination represents the optimal α during each iteration.

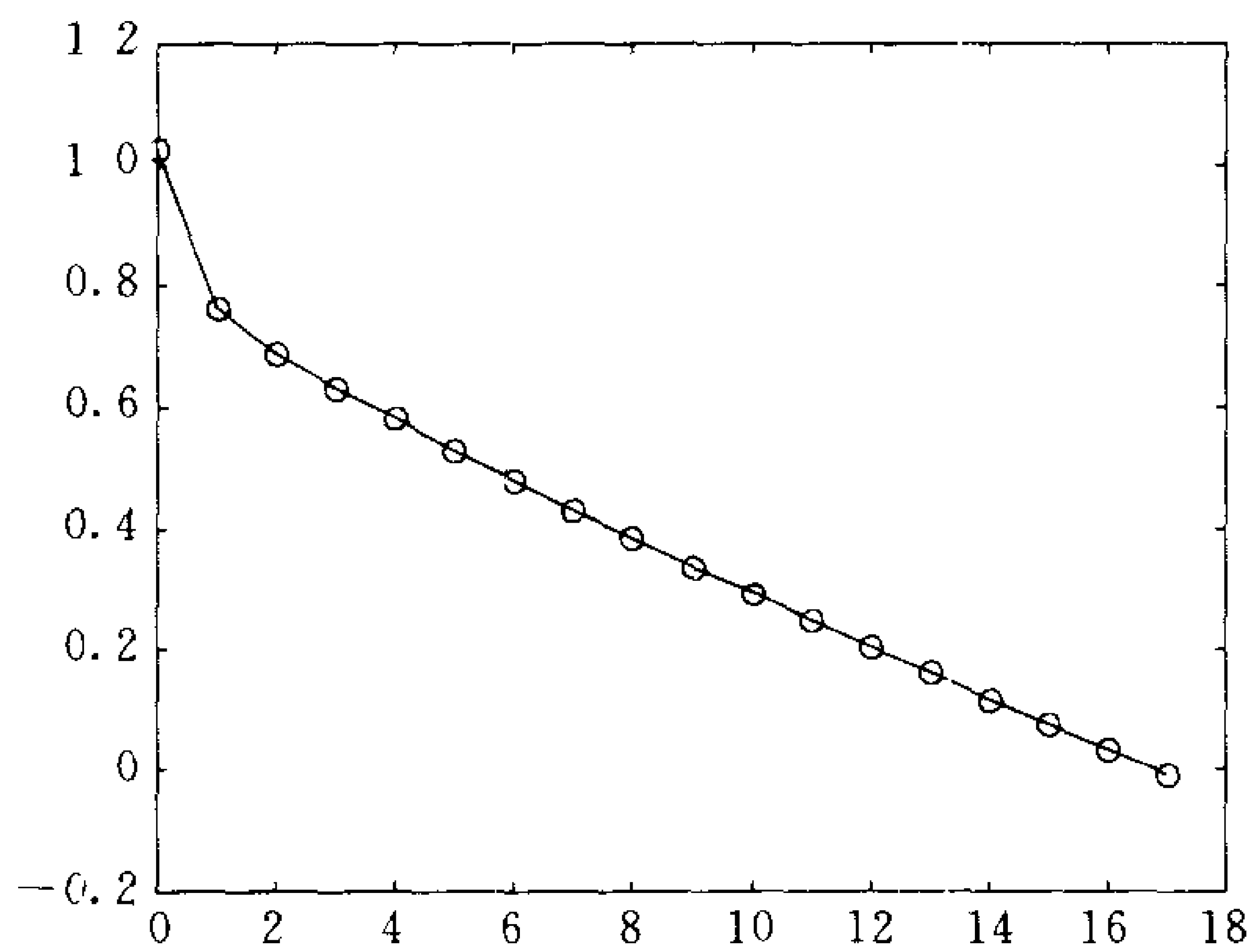

Fig. 1 Plot of $\alpha(t)$ with respect to the iterative number

4) Validation

The eigenvalues of the open-loop and closed-loop systems are illustrated as Tables 1~2. It can be shown that the open-loop system is unstable for $\varepsilon \in (0, 0.3]$, whereas the closed-loop system is stable.

Table 1 Plant 1

ε	Open-loop	Closed-loop
0.05	−0.5933 ± 1.1912i 4.7683 ±16.8494i	−46.078 ±41.952i −0.2688 ± 1.1496i
0.1	−0.6113 ± 1.1697i 2.4613± 8.4782i	−23.149 ±21.257i −0.2620± 1.1408i
0.2	−0.6453 ± 1.1224i 1.3328 ± 4.2981i	−11.693 ±10.904i −0.2498 ± 1.1229i
0.3	−0.6703 ± 1.0685i 0.9703 ± 2.9224i	−7.880 ± 7.448i −0.2395 ± 1.1051i

Table 2 Plant 2

ε	Open-loop	Closed-loop
0.05	20.5424, −14.8002 −0.1411 ± 0.6686i	−78.599, −16.0003 −2.7937, −0.0142
0.1	10.2714, −7.4189 −0.1363± 0.6687i	−39.1625, −7.9595 −0.0152, −2.6285
0.2	5.1287, −3.7346 −0.1271± 0.6686i	−19.6575, −4.0891 −2.1804, −0.0178
0.3	3.4086, −2.5112 −0.1187 ± 0.6683i	−13.3697, −3.0016 −1.6117, −0.0214

5 Conclusions

The main contribution of this paper is that the simultaneous stabilization for a finite collection of singularly perturbed plants, which has not been investigated, is solved in the frame of ILMI method. Since no fixed structure has been constrained to the selection of the control gain, it can be easily extended to the simultaneous stabilization for more singularly perturbed plants, which is a very difficult problem via Riccati equations. Finally, the approach proposed here can also be used for the H_∞ control, optimal control, *etc*.

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基于迭代线性矩阵不等式的奇异摄动系统同时镇定

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摘 要 研究了采用一个线性状态反馈控制器镇定多个线性奇异摄动系统的问题.同时镇定条件可以表达为一组矩阵不等式条件，所得条件与摄动参数无关，从而有效地回避了病态问题.采用基于快慢分解的两步法可以得到镇定控制器增益和相应的Lyapunov函数.而在每一步需要利用迭代线性矩阵不等式技术求解相应的双线性矩阵不等式，相关定理研究了算法的收敛性.本文所得结论可同时适用于标准与非标准奇异摄动系统.文末给出了相应的仿真算例.

关键词 线性矩阵不等式，奇异摄动，同时镇定
中图分类号 TP13

第23届中国控制会议征文通知

中国控制会议是由中国自动化学会控制理论专业委员会组织召开的国际性学术会议，每年举办一次.其宗旨是为海内外系统控制领域的专家、学者、研究生及工程设计人员提供一个学术交流的机会，以便推动系统与控制科学的发展.第23届中国控制会议定于2004年8月10-13日在无锡市湖滨饭店举行.我们热忱欢迎世界各地的同仁参加本届大会.

征文范围如下：

S1 系统理论与控制理论	S2 非线性系统	S3 复杂性与复杂系统理论	S4 建模、辨识与估计
S5 优化控制与优化方法	S6 鲁棒控制与 H-inf 控制	S7 学习控制	S8 稳定性与镇定
S9 自适应控制	S10 变结构控制	S11 分布参数系统	S12 混合系统与 DEDS
S13 大系统理论与方法	S14 神经网络与控制	S15 模糊系统与控制	S16 故障诊断
S17 CIMS 与制造系统	S18 仿真与控制系统 CAD	S19 智能信息处理系统	S20 遗传算法与智能计算
S21 分布式控制系统	S22 运动控制	S23 智能机器人	S24 电力系统
S25 环境与生物工程	S26 人机系统	S27 智能仪表	S28 智能交通系统
S29 社会经济系统与控制	S30 各种应用		

征文要求：

稿件内容包括：① 首页：论文所属方向（选自征文范围）、论文题目、摘要、3～5个关键词、联系人的姓名、职称、地址、邮编、电话、E-mail；② 论文题目、摘要、3～5个关键词、正文（中、英文均可）；③ 凡邀请组论文，请将①中的首页和论文的详细摘要交组织者，由组织者统一投稿.

投稿可以直接邮寄至程序委员会秘书处，也可以通过E-mail.直接邮寄论文需一式2份.

大会设立关肇直优秀论文奖，申请办法和条例请查看会议网页：http://ccc.iss.ac.cn/

拟组织邀请组的组织者，请提供1000字的组织建议书及该组全部拟邀请论文的首页和详细摘要.同一邀请组的论文的主题应鲜明、集中，邀请组一般有6篇论文.

重要日期：

提交论文的截止日期：2004年3月31日； 录用/不录用通知日期：2004年4月30日前；
提交最终论文截止日期：2004年5月31日

投稿地址：

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