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Stabilization Decomposition of Neutral Linear Time-Varying Interconnected Control Systems with the Multi-Group Multi-Delays*

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Abstract: Some concepts of the structure and interconnected stabilization of the neutral linear time-varying interconnected control system with multigroup multidelays and perturbation parameters are established. A positive definite quadratic form V-function via choosing the symmetric positive definite solution matrix of Riccati matrix defferential equation is made up. On the base of the equivalence method of Lyapunov's function, the interconnected stabilization of the linear time-varying control system without delays and perturbation parameters imply the interconnected stabilization of the neutral linear time-varying interconnected control system with multigroup multidelays and perturbation parameters. At the same time, the estimate formulae of the bounded for both time-delays and perturbation parameters are given.

Key words: interconnected stabilization; equivalence method of Lyapunov's function; neutral type; control system; multi-group multi-delays

1 Questions and Methodic Formulation

The concept of the structure and interconnected stability for large scale continuous dynamic system had been formulated by Siljak, D. D. [1], and had analyzed them for continuous large scale system in a systematic way. In 1994, Liu Yongqing and Zhang Xinzheng[2] had studied the structure and interconnected stabilization problems of the linear time-varying interconnected control system with the multi-group multi-delays and perturbation parameters

$$\dot{x}_i(t)=\sum_{j=1}^{n}a_{ij}(t)x_j(t)+\sum_{f=1}^{m}b_{if}(t)u_f(t)+\sum_{r=1}^{N_1}\sum_{j=1}^{n}a_{1ij}^{(r)}(t)e_{1ij}^{(r)}(t)x_j(t)$$
$$+\sum_{s=1}^{N_2}\sum_{j=1}^{n}a_{2ij}^{(s)}(t)e_{2ij}^{(s)}(t)x_j(t-\tau_{1ij}^{(s)})+\sum_{d=1}^{N_3}\sum_{f=1}^{m}b_{1if}^{(d)}e_{3if}^{(d)}(t)u_f(t),\quad i=1,\cdots,n. \tag{1.1}$$

$$y_g(t)=\sum_{j=1}^{n}c_{gj}(t)x_j(t)+\sum_{h=1}^{N_4}\sum_{j=1}^{n}c_{1gj}^{(h)}(t)e_{4gj}^{(h)}(t)x_j(t),\quad g=1,\cdots,p. \tag{1.1a}$$

In engineering and social practice, propagation of any signal and information is always to exist time delays. Due to the existence of some perturbation factor, enabling some loop tem-

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proary interruption or get on again, this kind of control system with the multigroup multidelays will take place some change in structure. Therefore, there are some problems of the structure and interconnected stability not only in the retarded interconnected control sysetms but also in the neutral interconnected control systems, namely, the control system bear relation to the rate of change $\dot{x}(t)$ and $\dot{x}(t-\tau)$ of the state variable $x(t)$. We are again in need of studying multilevel hierarchy multi-loops negative feedback interconnected control system in practice, now, that is appearing from structure and interconnected stabilization problem of the neutral linear or nonlinear continuous interconnected control systems with multigroup multidelays, its mathematical model is always neutral differential equation with time delay variables. The problems of the interconnected control system are naturally in infinitive dimension space, so the interconnected stabilization of the neutral linear time-varying interconnected control system with the multi-group multi-delays becomes more difficult and more complicated. In this paper, based on the equivalence method of Lyapunov's function given by Liu Yongqing, the problem is solved.

2 Structure and Interconnected Stabilization

Considering a neutral linear time-varying interconnected control system with the multigroup multidelays

$$\begin{aligned}\dot{x}_i(t)= &\sum_{j=1}^{n}\bar{a}_{ij}(t)x_j(t)+\sum_{f=1}^{m}\bar{b}_{if}(t)u_f(t)+\sum_{r=1}^{N_1}\sum_{j=1}^{n}\bar{a}_{1ij}^{(r)}(t)e_{1ij}^{(r)}(t)x_j(t)\\ &+\sum_{s=1}^{N_2}\sum_{j=1}^{n}\bar{a}_{2ij}^{(s)}(t)e_{2ij}^{(s)}(t)x_j(t-\tau_{1ij}^{(s)})+\sum_{l=1}^{N_3}\sum_{j=1}^{n}\bar{a}_{3ij}^{(l)}(t)e_{3ij}^{(l)}\dot{x}_j(t-\tau_{2ij}^{(l)})\\ &+\sum_{d=1}^{N_4}\sum_{f=1}^{m}\bar{b}_{1if}^{(d)}(t)e_{4ij}^{(d)}(t)u_f(t),\quad i=1,\cdots,n. \end{aligned} \tag{2.1}$$

$$y_g(t)=\sum_{j=1}^{n}\bar{c}_{gj}(t)x_j(t)+\sum_{h=1}^{N_5}\sum_{j=1}^{n}\bar{c}_{1gj}^{(h)}(t)e_{5gj}^{(h)}(t)x_j(t),\quad g=1,\cdots,p. \tag{2.1a}$$

$x(t)=\phi(t), \dot{x}(t)=\dot{\phi}(t), u(t)=\psi(t), -\tau\leqslant t\leqslant 0, \tau=\max\{\tau_1,\tau_2\}, \tau_1=\max\limits_{1\leqslant i,j\leqslant n}\{\tau_{1ij}^{(s)}; s=1,\cdots,N_2\}, \tau_2=\max\limits_{1\leqslant i,j\leqslant n}\{\tau_{2ij}^{(l)}; l=1,\cdots,N_3\}$, $\psi(t)$ is a given continuous derivable initial vector function, $\psi(t)$ is a given continuous initial vector function. $I-\sum_{l=1}^{N_3}\widetilde{A}_3^{(l)}(t)$ is non-singular for $t\geqslant t_0$, where $\widetilde{A}_3^{(l)}(t)=(\bar{a}_{3ij}^{(l)}(t)e_{3ij}^{(l)}(t))_{n\times n}$ and $\|\sum_{l=1}^{N_3}\widetilde{A}_3^{(l)}(t)\|<1, t\geqslant t_0$ then (2.1), (2.1a) can be rewritten as

$$\begin{aligned}\dot{x}_i(t)= &\sum_{j=1}^{n}a_{ij}(t)x_j(t)+\sum_{f=1}^{m}b_{if}(t)u_f(t)+\sum_{f=1}^{N_1}\sum_{j=1}^{n}a_{1ij}^{(r)}(t)e_{1ij}^{(r)}(t)x_j(t)\\ &+\sum_{s=1}^{N_2}\sum_{j=1}^{n}a_{2ij}^{(s)}(t)e_{2ij}^{(s)}(t)x_j(t)+\sum_{s=1}^{N_2}\sum_{j=1}^{n}a_{2ij}^{(s)}(t)e_{2ij}^{(s)}(t)[x_j(t-\tau_{1ij}^{(s)})-x_j(t)]\\ &+\sum_{l=1}^{N_3}\sum_{j=1}^{n}a_{3ij}^{(l)}(t)e_{3ij}^{(l)}(t)[\dot{x}_j(t-\tau_{2ij}^{(l)})-\dot{x}_j(t)]+\sum_{d=1}^{N_4}\sum_{f=1}^{m}b_{1if}^{(d)}(t)e_{4if}^{(d)}(t)u_f(t)\end{aligned}$$

$$\equiv F_{1i}(\cdot), \quad i = 1,\cdots,n, \tag{2.2}$$

$$y_g(t) = \sum_{j=1}^{n} c_{gj}(t)x_j(t) = F_{2g}(\cdot), \quad g = 1,\cdots,p, \tag{2.2a}$$

where I is an identity matrix;

$$A(t) = (a_{ij}(t))_{n\times n} = (I - \sum_{l=1}^{N_3}\tilde{A}_3^{(l)}(t))^{-1}(\bar{a}_{ij}(t) + \sum_{r=1}^{N_1}\bar{a}_{1ij}^{(r)}(t)e_{1ij}^{(r)}(t) + \sum_{s=1}^{N_2}\bar{a}_{2ij}^{(s)}(t)e_{2ij}^{(s)}(t))_{n\times n},$$

$$B(t) = (b_{if}(t))_{n\times m} = (I - \sum_{l=1}^{N_3}\tilde{A}_3^{(l)}(t))^{-1}(\bar{b}_{if}(t) + \sum_{d=1}^{N_4}\bar{b}_{1if}^{(d)}(t)e_{1if}^{(d)}(t))_{n\times m},$$

$$A_1^{(r)}(t) = (a_{1ij}^{(r)}(t))_{n\times n} = (I - \sum_{l=1}^{N_3}\tilde{A}_3^{(l)}(t))^{-1}(\bar{a}_{1ij}^{(r)}(t))_{n\times n}, \quad (r = 1,\cdots,N_1),$$

$$A_2^{(s)}(t) = (a_{2ij}^{(s)}(t))_{n\times n} = (I - \sum_{l=1}^{N_3}\tilde{A}_3^{(l)}(t))_{n\times n}^{-1}(\bar{a}_{2ij}^{(s)}(t))_{n\times n}, \quad (s = 1,\cdots,N_2),$$

$$A_3^{(l)}(t) = (a_{3ij}^{(l)}(t))_{n\times n} = (I - \sum_{l=1}^{N_3}\tilde{A}_3^{(l)}(t))^{-1}(\bar{a}_{3ij}^{(l)}(t))_{n\times n}, \quad (l = 1,\cdots,N_3),$$

$$C(t) = (c_{gj}(t))_{p\times n} = (\bar{c}_{gj}(t) + \sum_{h=1}^{N_6}\bar{c}_{1gj}^{(h)}(t)\bar{e}_{6gj}^{(h)}(t),$$

delays $\tau_{1ij}^{(s)} > 0, (s = 1,\cdots,N_2), \tau_{2ij}^{(l)} > 0, (l = 1,\cdots,N_3; i,j = 1,\cdots,n)$ are constants or functions of variable t. And vectors $x(t) = (x_1(t),\cdots,x_n(t))^{\mathrm{T}}, u(t) = (u_1(t),\cdots,u_m(t))^{\mathrm{T}}$, and $y(t) = (y_1(t),\cdots,y_p(t))^{\mathrm{T}}$; e_{ij} is the element of $N\times N$ interconnected matrix; $E = (e_{ij})$ which is generated by fundamental interconnected matrix $\bar{E} = (\bar{e}_{ij})$ (denoted by $E \in \bar{E}$), i. e., where e_{ij} is either 0 or 1.

Definition 1 For delays $\tau_{1ij}^{(s)} \geqslant 0$ $(s = 1,\cdots,N_2), \tau_{2ij}^{(l)} \geqslant 0$ $(l = 1,\cdots,N_3; i,j = 1,\cdots,n)$ and mutual connection matrices $E_\beta^{(\alpha)}(t) \in \bar{E}_\beta^{(\alpha)}(t)$ $(\alpha = r,s,l,d,h; \beta = 1,2,3,4,6)$, if the trivial sloution of the closed-loop system of the multi-group multi-delays and perturbation parameters neutral nonlinear time-varying interconnected control systems with the time-delay control vector functions (2.2) is asymptotically stable, then we call the system (2.1) is interconnected stabilization.

In the neutral interconnected control systems with the multigroup multidelays (2.1), when $z = 0$, if we don't consider the perturbation structure interconnected term and the perturbation interconnnected term, then (2.1), (2.1a) become linear constant time-varying control systems without delays and perturbation structure parameter

$$\dot{x}(t) = A(t)x(t) + B(t)u(t), \tag{2.3}$$

$$y(t) = C(t)x(t), \tag{2.3a}$$

where

$$A(t) = (\bar{a}_{ij}(t))_{n\times n}, \quad B(t) = (\bar{b}_{if}(t))_{n\times m}, \quad C(t) = (\bar{c}_{gj}(t))_{p\times n}.$$

Assume that the matrix pair $(A(t); B(t))$ is uniformly completely controllable, and the matrix pair $(A(t); C(t))$ is uniformly completely observable for any $t \in (t_0, +\infty)$, then it is possible to choose optimal negative feedback vector function

$$u(t) = -K(t)x(t), \tag{2.4}$$

which minimizes the performance index of the quadratic form for system (2. 3), (2. 3a)

$$J = \int_{t_0}^{+\infty} [x^{\mathrm{T}}(t)Q(t)x(t) + u^{\mathrm{T}}(t)R(t)u(t)]\mathrm{d}t, \tag{2.5}$$

such that the characteristic roots of characteristic equation

$$H(\lambda) = |A(t) - B(t)K(t) - \lambda(t)I| = 0, \tag{2.6}$$

for closed-loop system of linear time-varying control system of (2. 3), (2. 3a)

$$\dot{x}(t) = (A(t) - B(t)K(t))x(t), \tag{2.7}$$

satisfy

$$\mathrm{Re}(\lambda(t)) < -\eta < 0, \tag{2.8}$$

where $\eta > 0$ is a constant, that is, the zero sloution of closed-loop system (2. 7) is uniformly asymptotically stable, where $K(t) = R^{-1}(t)B^{\mathrm{T}}(t)P(t) \triangleq (k_{fj}(t))_{m\times n}$ for any $t \geqslant t_0$ P is the only one symmetric positive definite solution of Riccati matrix differential nonlinear equation

$$\dot{P}(t) + A^{\mathrm{T}}(t)P(t) + P(t)A(t) - P(t)B(t)R^{-1}(t)B^{\mathrm{T}}(t)P(t) + Q(t) = 0, \tag{2.9}$$

where $R(t)$ and $Q(t) = C^{\mathrm{T}}(t)C(t)$ are $m \times m$ and $n \times n$ symmetric positive definite time-varying matrix, respectively.

By using the symmetric positive definite solution $P(t)$ of (2. 9) to construct a symmetric positive definite V-function of the quadratic form

$$V(x(t)) = x^{\mathrm{T}}(t)P(t)x(t). \tag{2.10}$$

Krusovskii point out that, for $V(x(t))$ in (2. 10), there are constants $\beta_1 > 0, \beta_2 > 0$, such that

$$\beta_1 x^{\mathrm{T}}(t)x(t) \leqslant V(x(t)) \leqslant \beta_2 x^{\mathrm{T}}(t)x(t). \tag{2.11}$$

Lemma 1 Assume that the matrix pair $(A(t):B(t))$ is uniformly completely controllable, and the matrix pair $(A(t):C(t))$ is uniformly completely observable, then there exists the positive definite function (2. 10) of quadratic form, such that

$$\dot{V}(x(t)) < 0, \tag{2.12}$$

that is , the zero solution of the linear time-varying closed-loop system (2. 7) is uniformly asymptotically stable.

Proof Calculating the derivative $\dot{V}(x(t))$ along the trajectory of closed-loop system (2. 7)

$$\begin{aligned} \dot{V}(x(t))_{(2.7)} &= [\dot{x}^{\mathrm{T}}(t)P(t)x(t) + x^{\mathrm{T}}(t)\dot{P}(t)x(t) + x^{\mathrm{T}}(t)P\dot{x}(t)]_{(2.7)} \\ &= x^{\mathrm{T}}(t)\dot{P}(t)x(t) + x^{\mathrm{T}}(t)A^{\mathrm{T}}(t)P(t)x(t) - x^{\mathrm{T}}(t)K^{\mathrm{T}}(t)B^{\mathrm{T}}(t)P(t)x(t) \\ &\quad + x^{\mathrm{T}}(t)P(t)A(t)x(t) - x^{\mathrm{T}}(t)P(t)B(t)K(t)x(t). \end{aligned} \tag{2.13}$$

By (2. 9), we have

$$\dot{P}(t) + A^{\mathrm{T}}(t)P(t) + P(t)A(t) - P(t)B(t)R^{-1}(t)B^{\mathrm{T}}(t)P(t) = -Q(t). \tag{2.14}$$

Putting (2. 14) into (2. 13), and paying attention to $K(t) = R^{-1}(t)B^{\mathrm{T}}(t)P(t)$, we obtain

$$\begin{aligned} \dot{V}(x(t))_{(2.7)} &= x^{\mathrm{T}}(t)(K^{\mathrm{T}}(t)B^{\mathrm{T}}(t)P(t) + Q(t))x(t) \\ &= -x^{\mathrm{T}}(t)(P(t)B(t)R^{-1}(t)B^{\mathrm{T}}(t)P(t) + Q(t))x(t). \end{aligned} \tag{2.15}$$

Due to

$$P(t)B(t)R^{-1}(t)B^{\mathrm{T}}(t)P(t)+Q(t)=P(t)B(t)R^{-1}(t)B^{\mathrm{T}}(t)P(t)+C^{\mathrm{T}}(t)C(t)$$

is a symmetric positive definite matrix, there are the maximum and the minimum characteristic values $\alpha_1>0,\alpha_2>0$, respectively, such that

$$\alpha_1x^{\mathrm{T}}(t)x(t)\leqslant x^{\mathrm{T}}(t)(P(t)B(t)R^{-1}(t)B^{\mathrm{T}}(t)P(t)+C^{\mathrm{T}}(t)C(t))x(t)\leqslant\alpha_2x^{\mathrm{T}}(t)x(t). \tag{2.16}$$

From (2.15) and (2.16) we obtain

$$\dot V(x(t))_{(2.7)}\leqslant-\alpha_1x^{\mathrm{T}}(t)x(t)<0. \tag{2.17}$$

This shows that the zero solution of closed-loop system (2.7) is uniformly asymptotically stable. The proof of Lemma 1 is completed.

Let

$$\begin{cases}\sup\limits_{t\geqslant t_0}\{|\tilde a_{ij}(t)|,|\tilde a_{1ij}^{(r)}(t)|,|\tilde a_{2ij}^{(s)}(t)|;i,j=1,\cdots,n,r=1,\cdots,N_1,s=1,\cdots,N_2\}=\bar a_1,\\ \sup\limits_{t\geqslant t_0}\{|\tilde a_{3ij}^{(l)}(t)|;i,j=1,\cdots,n,l=1,\cdots,N_3\}=\tilde a_1',\\ \sup\limits_{t\geqslant t_0}\{|\tilde b_{if}(t)|,|\tilde b_{1if}^{(d)}(t)|,|\tilde b_{2if}(t)|;i=1,\cdots,n,f=1,\cdots,m,d=1,\cdots,N_5\}=\bar b_1,\\ \sup\limits_{t\geqslant t_0}\{|a_{1ij}^{(r)}(t)|,|a_{2ij}^{(s)}(t)|;i,j=1,\cdots,n,r=1,\cdots,N_1,s=1,\cdots,N_2\}=a_1,\\ \sup\limits_{t\geqslant t_0}\{|a_{3ij}^{(l)}(t)|;i,j=1,\cdots,n,l=1,\cdots,N_3\}=a_1',\\ \sup\limits_{t\geqslant t_0}\{|b_{1if}^{(d)}(t)|,|b_{2if}^{(d)}(t)|;i=1,\cdots,n,f=1,\cdots,m,d=1,\cdots,N_4\}=b_1,\\ \sup\limits_{t\geqslant t_0}\{|p_{ij}(t)|;i,j=1,\cdots,n\}=p_1,\\ \sup\limits_{t\geqslant t_0}\{|k_{fj}(t)|;f=1,\cdots,m,j=1,\cdots,n\}=k_1,\\ \max\{a_1,b_1\}=D_1.\end{cases} \tag{2.18}$$

Regarding (2.4) as the suboptimal negative feedback vector function of (2.1) with the multigroup multidelays, we obtain a closed-loop system

$$\begin{aligned}\dot x_i(t)=&\sum_{j=1}^n\tilde a_{ij}(t)x_j(t)-\sum_{j=1}^n\sum_{f=1}^m\tilde b_{if}(t)k_{fj}(t)x_j(t)\\&+\sum_{r=1}^{N_1}\sum_{j=1}^n\tilde a_{1ij}^{(r)}(t)e_{1ij}^{(r)}(t)x_j(t)+\sum_{s=1}^{N_2}\sum_{j=1}^n\tilde a_{2ij}^{(s)}(t)e_{2ij}^{(s)}(t)x_j(t-\tau_{1ij}^{(s)})\\&+\sum_{l=1}^{N_3}\sum_{j=1}^n\tilde a_{3ij}^{(l)}(t)e_{3ij}^{(l)}(t)\dot x_j(t-\tau_{2ij}^{(l)})\\&-\sum_{d=1}^{N_4}\sum_{j=1}^n\sum_{f=1}^m\tilde b_{1if}^{(d)}(t)e_{4if}^{(d)}(t)k_{fj}(t)x_j(t),\quad i=1,\cdots,n.\end{aligned} \tag{2.19}$$

Lemma 2 Assume that $nN_3a_1'<1$, and $x(t)$ is a solution of (2.19), and $\|x(t)\|<\delta$, $\|\dot x(t)\|<\delta$, $\|\ddot x(t)\|$ is bounded when $t-\tau\leqslant t\leqslant t_0$. If $\|x(t)\|\leqslant N$ $(t_0-\tau\leqslant t\leqslant t_1$, $t_0<t_1)$, then

$$\|\dot x(t)\|\leqslant h_1N,\quad \|\ddot x(t)\|\leqslant h_1'N,$$

where

$$h_1 = n(\tilde{d}_1 + N_1\tilde{a}_1 + N_2\tilde{a}_1 + N_4\tilde{b}_1 mk_1 + N_5\tilde{b}_1 mk_1)/(1 - nN_3\tilde{a}_1'), \quad h_1' = h_1^2,$$

$$\tilde{d}_1 = \sup\{|\tilde{a}_{ij}(t) - \sum_{f=1}^{m}\tilde{b}_{if}(t)k_{fj}(t)|; i,j = 1,\cdots,n\}.$$

N can be a constant or a function of variable t.

Proof The proof of Lemma 2 is similar as that of corresponding theorem in [4], we omit it here.

Lemma 3 Assume that the conditions of Lemma 2 are satisfied, then we have the estimate formulae as the following:

$$|x_j(t-\tau_{1ij}^{(s)}) - x_j(t)| = |\int_{t-\tau_{1ij}^{(s)}}^{t} \dot{x}_j(\zeta)\mathrm{d}\zeta| \leqslant |\tau_{1ij}^{(s)}||\dot{x}_j(t_{ij}^{(s)})| \leqslant \tau\max\{|\dot{x}_j(t_{ij}^{(s)})|\}$$

$$= \tau|\dot{x}_j(t_j')| \leqslant \tau\{\sum_{i=1}^{n}[(N_1+1)\bar{a}_1|x_i(t_j')| + \bar{a}_1\sum_{s=1}^{N_2}|x_i(t_j' - \tau_{1ij}^{(s)})|$$

$$+ \bar{a}_1'\sum_{l=1}^{N_3}|x_i(t_j' - \tau_{2ji}^{(l)})|] + (N_4+1)\bar{b}_1\sum_{f=1}^{m}|u_f(t_j')|\}$$

$$\leqslant \tau\{\sum_{i=1}^{n}[(N_1+1)\bar{a}_1 + (N_4+1)\bar{b}_1k_1m]|x_i(t_j')|$$

$$+ \bar{a}_1\sum_{s=1}^{N_2}|x_i(t_j' - \tau_{1ji}^{(s)})| + \bar{a}_1'h_1\sum_{l=1}^{N_3}|x_i(t_j' - \tau_{2ji}^{(l)})|\}, \tag{2.20}$$

the last inequality has used the following formula:

$$|u_f(t)| \leqslant \sum_{j=1}^{n}|k_{fj}(t)||x_j(t)| \leqslant k_1\sum_{j=1}^{n}|x_j(t)|, \quad f = 1,\cdots,m. \tag{2.21}$$

$$|\dot{x}_f(t-\tau_{2ij}^{(l)}) - x_j(t)| = |\int_{t-\tau_{1ij}^{(s)}}^{t}\ddot{x}_j(\zeta)d\zeta| \leqslant |\tau_{2ij}^{(l)}||\ddot{x}_j(t_{ij}^{(l)})| \leqslant \tau\max\{|\ddot{x}_j(t_{ij}^{(l)})|\}$$

$$= \tau|\ddot{x}_j(t_j'')| \leqslant \tau h_1'|x_j(t_j'')| \leqslant \tau h_1'\sum_{i=1}^{n}x_j(t_j')|, \tag{2.22}$$

where $t - \tau_{1ij}^{(s)} \leqslant t_j' \leqslant t, t - \tau_{2ij}^{(l)} \leqslant t_j'' \leqslant t$. Defining a set B as the following:

$$B = \{X; X \in \mathbb{R}^n, V(X) \leqslant 4V(x_1(t),\cdots,x_n(t))\}. \tag{2.23}$$

Lemma 4 If $P_j = (x_1(t_j - \tau_{ji}),\cdots,x_n(t_j - \tau_{jn})) \in B$, then

$$\max\{\sum_{i=1}^{n}x_i^2(t_j - \tau_{ji}), \sum_{i=1}^{n}x_i^2(t_j)\} \leqslant \beta_{11}\sum_{i=1}^{n}x_i^2(t), \tag{2.24}$$

where $\beta_{11} = 4\beta_2/\beta_1$ is a positive constant.

Owing to the two sum-sign items at the head of (2.2) is the right side of linear time-varying control system (2.3) which is without time delay and perturbation structure parameter, while five sum-sign items at the back of (2.2) can be regarded as the perturbed term of control system (2.2) with the multigroup multidelays. When there aren't perturbation, $a_1 = b_1 = \tau = 0$, second of (2.2) equals zero. Therefore, when perturbation structure parameter a_1, b_1 and delays $\tau_{1ij}^{(s)}, \tau_{2ij}^{(l)}$, are very small, regarding the five sum-sign items at the back of (2.2) as the perturbation term of (2.3). Therefore, taking (2.3) as the negative feedback vector function of control system (2. 1) or (2. 2), and taking (2. 10) as the symmetric positive definite Lyapunov's V-function of the quadratic form of control system (2. 1) or (2. 2), we can obtain the following Theorem 1:

Theorem 1 Suppose that $\| \sum_{l=1}^{N_3} \widetilde{A}_3^{(l)}(t) \| < 1$, $I - \sum_{l=1}^{N_3} \widetilde{A}_3^{(l)}(t)$ is a non-singular matrix, for any $t \geqslant t_0$, the conditions of Lemma 2 are satisfied, $(A(t):B(t))$ is uniformly controllable, $(A(t):C(t))$ is uniformly completely observable, then for $\forall\, E_\beta^{(\alpha)}(t) \in \overline{E}_\beta^{(\alpha)}(t)$, there are constants $\Delta_1 > 0$ and $\Delta_2 > 0$, uniform symptotical stabilization of the trivial solution of closed-loop system of system (2. 3) implies the uniform interconnected asymptotical stabilization for the neutral time-varying closed-loop control system (2. 2) or (2. 1) with the multigroup multidelays if

$$0 \leqslant D_1 < \Delta_1, \quad 0 \leqslant \tau < \Delta_2, \tag{2.25}$$

where

$$\Delta_1 = \alpha_1[2p_1 n^2(N_1 + N_2 + k_1 m N_4)]^{-1} \tag{2.26}$$

$$\Delta_2 = \alpha_1\{p_1 n^3(1 + \beta_{11})[a_1 N_2((N_1 + N_2 + 1)\bar{a}_1 + N_3 h_1 \bar{a}_1' + (N_4 + 1)\bar{b}_1 k_1 m) + N_3 h_1' a_1']\}^{-1}. \tag{2.27}$$

Proof The proof is omitted here.

Theorem 2 Suppose that $\| \sum_{l=1}^{N_3} \widetilde{A}_3^{(l)}(t) \| < 1$, $I - \sum_{l=1}^{N_3} \widetilde{A}_3^{(l)}(t)$ is non-singular matrix, for any $t \geqslant t_0$, the conditions of Lemma 2 are satisfied, and the trivial solution of the linear time-varying closed-loop system (2. 7) of (2. 3) is uniformly asymptotically stable, then there exist constants $\Delta_1 > 0$ and $\Delta_2 > 0$, such that for $\forall\, E_\beta^{(\alpha)}(t) \in \overline{E}_\beta^{(\alpha)}(t)$ $(\beta = 1,2,3,4,6;\ \alpha = r,s,l,d,h)$, the trivial solution of the closed-loop system of the neutral linear time-varying control system (2. 2) or (2. 1) with the multigroup multidelays is the interconnected uniformly asymptotically stabilization if

$$0 \leqslant D_1 < \Delta_1, \quad 0 \leqslant \tau < \Delta_2. \tag{2.28}$$

Proof The proof is analogous to that of Theorem 1 and therefore is omitted.

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多组多滞后中立型线性时变关联控制系统的结构与关联镇定

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摘要：建立了具有扰动参数的多组多滞后中立型线性时变关联控制系统的结构与关联镇定新概念.采用李雅普诺夫函数鲁棒镇定等价法,给出了由无滞后无扰动参数线性时变控制系统的关联镇定,蕴含了具有扰动结构参数的多组多滞后中立型线性时变关联控制系统的关联镇定的充分性判据,同时给出了扰动参数与滞后项界限的估计公式.

关键词：多组多滞后；关联镇定；李雅普诺夫函数等价法；中立型；控制系统

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