Stability Analysis Of Uncertain Neutral-Type Systems

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***Abstract*—This paper studies the problem of the stability analysis for uncertain neutral-type systems. By constructing an appropriate Lyapunov-Krasovskii functional, some new delay-dependent criteria can be obtained by using the free-weighting matrices approach to estimate the derivative of the Lyapunov functional, which are established in terms of linear matrix inequalities (LMIs). The novelties in this paper are that any bounding technique and any mode transformation method are not utilized. Finally, a numerical example is presented to illustrate the effectiveness of the proposed method.**

Keywords*— *Stability analysis, Neutral systems, Lyapunov method, Linear Matrix Inequality

I. Introduction

Time delays are frequently encountered in many practical engineering systems, such as chemical processes, long transmission lines in pneumatic systems [1]-[8]. It has been shown that the presence of a time delay in a dynamical system is often a primary source of instability and performance degradation [9]. Delay-dependent robust stability criteria of uncertain fuzzy systems with state and input delays are presented in [10]. Dynamical systems with distributed time-varying delays have been of considerable interest for the fast few decades. In particular, the interest in stability analysis of various delay differential systems has been growing rapidly due to their successful applications in practical fields such as circuit theory, aircraft stabilization, population dynamics, distributed networks, manual control and so on. Current efforts on the problem of stability of distributed time-varying delays system can be divided into two categories, namely delay independent criteria and delay dependent criteria. Distributed delay systems have been considered in [11]-[28].

The issue of stability for uncertain neutral systems using Linear Matrix Inequalities (LMI) approach is studied in this paper. We established a new LMI condition by using the Lyapunov-Krasovskii functional to guarantee the asymptotic stability of the system concerned. A sufficient condition for the solvability of this problem is proposed in terms of Linear Matrix Inequalities (LMIs) and the validity of this result is checked numerically using the effective LMI control toolbox in MATLAB.

NOTATIONS: Throughout this paper, for a matrix B and two symmetric matrices A and C,

$$\begin{bmatrix} A & B \\ & C \\ & \end{bmatrix}$$

denote the symmetric matrix, where the notation * represents the entries implied by symmetry. A^T and A^{-1} are denotes the matrix transpose and inverse of A respectively. We say $X > 0$ for $X \in \Re^n$ means that the matrix X is real symmetric positive definite. $\|\cdot\|$ refers to the Euclidean norm for vectors. And I denotes the identity matrix with appropriate dimensions.

II. Problem Formulation and Main Results

Consider the following uncertain Neutral-type neural networks with discrete and distributed delay.

$$\begin{cases} \dot{x}(t) = -A(t)x(t) + W_0(t)f(x(t)) + W_1(t)f(x(t-\tau)) + \\ x(\theta) = \phi(\theta), \forall \theta \in [-\eta, 0], \eta = max\{h, \tau, r\} \end{cases}$$

(1)

Where $x(t) \in R^n$ is the state vector. h, τ, t represent the neutral-delay, discrete delay and distributed-delay, respectively. The initial condition $\phi(t)$ denotes a continuous vector-valued initial function on the interval $[-\eta, 0]$. A, W_0, W_1, C and $W_2 \in R^{n\times n}$ are constant matrices, For system (1), the nominal form is given as follows:

$$\begin{cases} \dot{x}(t) = -Ax(t) + W_0 f(x(t)) + W_1 f(x(t-\tau)) + C\dot{x}(t-h \\ x(\theta) = \phi(\theta), \forall \theta \in [-\eta, 0], \eta = max\{h, \tau, r\}. \end{cases}$$

(2)

III. Main Results

Theorem 3.1 For three given scalars $h > 0$, $\tau > 0$, and $r > 0$, if there exist some positive definite symmetric matrices: P_{11}, P_{22}, P_{33}, P_{44}, $Q_i (i = 1,2,......,8) \in R^{n\times n}$ and some appropriately dimensional matrices: $(P_{ij})_{1\le i<j\le 4}$, $K = [K_1^T, K_2^T]^T$, $L = [L_1^T, L_2^T]^T$, $M = [M_1^T, M_2^T]^T$, $N = [N_1^T, N_2^T]^T$, such that the following linear matrix inequalities (LMIS) hold.

$$P=\begin{bmatrix} P_{11} & P_{12} & P_{13} & P_{14} \\ * & P_{22} & P_{23} & P_{24} \\ * & * & P_{33} & P_{34} \\ * & * & * & P_{44} \end{bmatrix}\geq 0, \qquad (3)$$

and

$$\Xi^1<0, \qquad (4)$$

$$\Xi^2<0,$$

Where,

$$\Xi^k=(\Omega_{ij}^k)_{9\times 9},$$

$\Omega_{11}^k=[-P_{11}A-A^TP_{11}^T+P_{13}^T+P_{13}+P_{14}^T+P_{14}-Q_1+Q_3+hQ_4+\tau Q_5+K_1^T+K_1+hL_1^T+hL_1+M_1+M_1^T$
$+\tau N_1^T+\tau N_1],$

$\Omega_{12}^k=[-A^TP_{12}+P_{23}^T-P_{13}+P_{24}^T-K_1^T+K_2+hL_2],\ \ \Omega_{13}^k=[P_{12}+P_{11}C],$

$\Omega_{14}^k=[-P_{14}-M_1^T+M_2+\tau N_2],\ \ \Omega_{15}^k=P_{11}W_0,\ \ \Omega_{16}^k=P_{11}W_1,$

$\Omega_{17}^k=P_{11}W_2,\ \ \Omega_{18}^1=h[-A^TP_{13}+P_{33}+P_{34}^T-L_1^T],$

$\Omega_{18}^2=\tau[-A^TP_{14}+P_{34}+P_{44}^T-N_1^T],\ \ \Omega_{19}^1=-hk_1^T-\frac{h^2}{2}L_1^T,\ \ \Omega_{19}^2=-\tau M_1^T-\frac{\tau^2}{2}N_1^T,$

$\Omega_{22}^k=[-P_{23}^T-P_{23}-K_2^T-K_1-Q_1],\ \ \Omega_{23}^k=[P_{22}+P_{12}^TC],\ \ \Omega_{24}^k=[-P_{24}],$

$\Omega_{25}^k=[P_{12}^TW_0],\ \ \Omega_{26}^k=[P_{12}^TW_1],\ \ \Omega_{27}^k=[P_{12}^TW_2],\ \ \Omega_{28}^1=h[-P_{33}-L_2^T],$

$\Omega_{28}^2=\tau P_{34},\ \ \Omega_{29}^1=-hk_2^T-\frac{h^2}{2}L_2^T,\ \ \Omega_{29}^2=0,\ \ \Omega_{33}^k=-Q_2,\ \ \Omega_{34}^k=0,$

$\Omega_{35}^k=0,\ \ \Omega_{36}^k=0,\ \ \Omega_{37}^k=0,\ \ \Omega_{38}^1=h[C^TP_{13}+P_{23}],$

$\Omega_{38}^2=\tau[C^TP_{14}+P_{24}],\ \ \Omega_{39}^k=0,\ \ \Omega_{44}^k=[-Q_3-M_2^T-M_2],\ \ \Omega_{45}^k=0,\ \ \Omega_{46}^k=0,\ \ \Omega_{47}^k=0,$

$\Omega_{48}^1=h[-P_{34}],\ \ \Omega_{48}^2=\tau[-P_{44}^T-N_2^T],\ \ \Omega_{49}^1=0,\ \ \Omega_{49}^2=-\tau M_2^T-\frac{\tau^2}{2}N_2^T,$

$\Omega_{55}^k=[r^2Q_8+S],\ \ \Omega_{56}^k=0,\ \ \Omega_{57}^k=0,\ \ \Omega_{58}^1=h[W_0^TP_{13}],\ \ \Omega_{58}^2=\tau[W_0^TP_{14}],$

$\Omega_{59}^k=0,\ \ \Omega_{66}^k=[-S],\ \ \Omega_{67}^k=0,\ \ \Omega_{68}^1=h[W_1^TP_{13}],\ \ \Omega_{68}^2=\tau[W_1^TP_{14}],\ \ \Omega_{69}^k=0,$

$\Omega_{77}^k=[-Q_8],\ \ \Omega_{78}^1=h[W_2^TP_{13}],\ \ \Omega_{78}^2=\tau[W_2^TP_{14}],\ \ \Omega_{79}^k=0,\ \ \Omega_{88}^1=[-hQ_4],$

$\Omega_{88}^2=[-\tau Q_5],\ \ \Omega_{89}^k=0,\ \ \Omega_{99}^1=[-hQ_6-\frac{h^2}{2}Q_9],\ \ \Omega_{99}^2=[-\tau Q_7-\frac{\tau^2}{2}Q_{10}],$

and * means the symmetric terms, then the nominal system (4) is asymptotically stable.

Proof: Define a Lyapunov-krasovskii functional candidate for system (4) as

$$V(t,x)=V_1(t,x)+V_2(t,x)+V_3(t,x), \qquad (6)$$

Where

$$V_1(t,x)=\xi^T(t)P\xi(t),$$

$$V_2(t,x)=\int_{t-h}^{t}x^T(s)Q_1x(s)ds+\int_{t-h}^{t}\dot{x}^T(s)Q_2\dot{x}(s)ds$$
$$+\int_{t-\tau}^{t}x^T(s)Q_3x(s)ds+\int_{t-\tau}^{t}f^T(x(s))Sf(x(s))ds,$$
$$V_3(t,x)=\int_{-h}^{0}\int_{t+\theta}^{t}x^T(s)Q_4x(s)dsd\theta+\int_{-\tau}^{0}\int_{t+\theta}^{t}x^T(s)Q_5x(s)dsd\theta$$
$$+\int_{-h}^{0}\int_{t+\theta}^{t}\dot{x}^T(s)Q_6\dot{x}(s)dsd\theta+\int_{-\tau}^{0}\int_{t+\theta}^{t}\dot{x}(s)Q_7\dot{x}(s)dsd\theta$$
$$+r\int_{-r}^{0}\int_{t+\theta}^{t}f^T(x(s))Q_8f(x(s))dsd\theta$$

Where

$$\xi(t)=\begin{bmatrix}x^T(t) & x^T(t-h) & \int_{t-h}^{t}x^T(s)ds & \int_{t-\tau}^{t}x^T(s)ds\end{bmatrix}.$$

Then, the time derivative of $V(t,x)$ with respect to t along the system (4) is .

$$\dot{V}(t,x)=\dot{V}_1(t,x)+\dot{V}_2(t,x)+\dot{V}_3(t,x), \tag{7}$$

Where

$$\dot{V}_1(t,x)=2[x^T(t)P_{11}+x^T(t-h)P_{12}^T+\int_{t-h}^{t}x^T(s)dsP_{13}^T+\int_{t-\tau}^{t}x^T(s)dsP_{14}^T]$$
$$[-Ax(t)+W_0f(x(t))+W_1f(x(t-\tau))+C\dot{x}(t-h)+W_2\int_{t-r}^{t}f(x(s))ds]$$
$$+2[x^T(t)P_{12}+x^T(t-h)P_{22}+\int_{t-h}^{t}x^T(s)dsP_{23}^T+\int_{t-\tau}^{t}x^T(s)dsP_{24}^T]\dot{x}(t-h)$$
$$+2[x^T(t)P_{13}+x^T(t-h)P_{23}+\int_{t-h}^{t}x^T(s)dsP_{33}+\int_{t_\tau}^{t}x^T(s)dsP_{34}^T][x(t)-x(t-h)]$$
$$+2[x^T(t)P_{14}+x^T(t-h)P_{24}+\int_{t-h}^{t}x^T(s)dsP_{34}+\int_{t-\tau}^{t}x^T(s)dsP_{44}][x(t)-x(t-\tau)], \tag{8}$$

$$\dot{V}_2(t,x)=x^T(t)[Q_1+Q_3]x(t)+x^T(t-h)[-Q_1]x(t-h)+\dot{x}^T(t)[Q_2]\dot{x}(t)$$
$$+\dot{x}^T(t-h)[-Q_2]\dot{x}(t-h)+x^T(t-\tau)[-Q_3]x(t-\tau)$$
$$+f^T(x(t-\tau))[-S]f(x(t-\tau))+f^T(x(t))[S]f(x(t)), \tag{9}$$

$$\dot{V}_3(t,x)=x^T(t)[hQ_4+\tau Q_5]x(t)+f^T(x(t))[r^2Q_8]f(x(s))$$
$$+\dot{x}^T(t)[hQ_6+\tau Q_7]\dot{x}(t)$$
$$-\int_{t-h}^{t}\dot{x}^T(s)[Q_4]x(s)ds-\int_{t-\tau}^{t}x^T(s)[Q_5]x(s)ds-\int_{t-h}^{t}\dot{x}^T(s)[Q_6]\dot{x}(s)ds$$

$$-\int_{t-\tau}^{t}\dot{x}^{T}(s)[Q_7]\dot{x}(s)ds - r\int_{t-r}^{t} f^{T}(x(s))[Q_8]f(x(s))ds. \quad (10)$$

By using the Jensen`s inequality

$$[\int_0^r w(s)ds]^T M[\int_0^r w(s)ds] \le r\int_0^r w^T(s)Mw(s)ds$$

We have,

$$\dot{V}_3(t,x) = x^T(t)[hQ_4 + \tau Q_5]x(t) + f^T(x(t))[r^2 Q_8]f(x(t))$$
$$+\dot{x}^T(t)[hQ_6 + \tau Q_7]\dot{x}(t)$$
$$-[\int_{t-h}^{t} x(s)ds]^T[Q_4]x(s) - [\int_{t-\tau}^{t} x(s)ds]^T[Q_5]x(s) - [\int_{t-h}^{t}\dot{x}(s)ds]^T[Q_6]\dot{x}(s)$$
$$-[\int_{t-\tau}^{t}\dot{x}(s)ds]^T[Q_7]\dot{x}(s) - [\int_{t-r}^{t} f(x(s))ds]^T[Q_8][\int_{t-r}^{t} f(x(s))ds]. \quad (11)$$

And from Leibinz-Newton Formula the following appropriate dimension, equating are true for real matrices K, L, M, N with an

$$\alpha_1(t) := 2\xi_1^T(t)K^T[x(t) - x(t-h) - \int_{t-h}^{t}\dot{x}(s)ds] = 0, \quad (12)$$

$$\alpha_2(t) := 2\xi_1^T(t)L^T[hx(t) - \int_{t-h}^{t} x(s)ds - \int_{-h}^{0}\dot{x}(s)dsd\theta] = 0, \quad (13)$$

$$\alpha_3(t) := 2\xi_2^T(t)M^T[x(t) - x(t-\tau) - \int_{t-\tau}^{t}\dot{x}(s)] = 0, \quad (14)$$

Where

$$\xi_1(t) = \begin{bmatrix} x^T(t) & x^T(t-h) \end{bmatrix}^T, \xi_2(t) = \begin{bmatrix} x^T(t) & x^T(t-\tau) \end{bmatrix}^T.$$

Suppose that

$$\sum_{i=1}^{4}\alpha_i(t) = x^T(t)[K_1^T + K_1 + hL_1^T + hL_1 + M_1^T + M_1]x(t)$$
$$+2x^T(t)[-K_1^T + K_2 + hL_2]x(t-h) + 2x^T(t)[-M_1^T + M_2]x(t-\tau)$$
$$+x^T(t-h)[-K_2^T - K_2]x(t-h) + x^T(t-\tau)[-M_2^T - M_2]x(t-\tau)$$
$$+x^T(t)[-hL_1^T]x(s) + 2x^T(t)[-hK_1^T - \frac{h^2}{2}L_1^T]\dot{x}(s)$$
$$+x^T(t) - \tau M_1^T\dot{x}(s)$$
$$+2x^T(t-h)[-hL_1^T]x(s)$$
$$+2x^T(t-h)[-hK_2^T - \frac{h^2}{2}L_2^T]\dot{x}(s) + 2x^T(t-\tau)[-\tau M_2^T]\dot{x}(s). \quad (15)$$

Combining from (10) to (15), we obtain

$$\dot{V}(t,x) = \dot{V}_1(t,x) + \dot{V}_2(t,x) + \dot{V}_3(t,x) + \sum_{i=1}^{4}\alpha_i(t),$$

$$\dot{V}(t,x) \le x^T(t)[-P_{11}^T A - P_{11}A^T + P_{13}^T + P_{13} + P_{14} + Q_1 + Q_3 + hQ_4 + \tau Q_5 + K_1^T + K_1$$

$$+ hL_1^T + hL_1 + M_1^T + M_1]x(t)$$

$$+2x^T(t)[-A^T P_{12} + P_{23}^T - P_{13} + P_{24}^T - K_1^T + K_2 + hL_2]x(t-h)$$

$$+2x^T(t)[P_{12} + P_{11}C]\dot{x}(t-h) + 2x^T(t)[-P_{14} - M_1^T + M_2]x(t-\tau)$$

$$+2x^T(t)[P_{11}W_0]f(x(t)) + 2x^T(t)[P_{11}W_1]f(x(t-\tau))$$

$$+2x^T(t)[P_{11}W_2]\int_{t-r}^{t} f(x(s))ds + 2x^T(t)h[-A^T P_{13} + P_{33} + P_{34}^T - L_1^T]x(s)$$

$$+2x^T(t)\tau[-A^T P_{14} + P_{34} + P_{44}^T]x(s)$$

$$+2x^T[-hK_1^T - \frac{h^2}{2}L_1^T]\dot{x}(s) + 2x^T(t)[-\tau M_1^T]\dot{x}(s)$$

$$+2x^T(t-h)[-P_{23}^T - P_{23} - K_2^T - K_1 - Q_1]x(t-h)$$

$$+2x^T(t-h)[P_{22} + P_{12}^T C]\dot{x}(t-h) + 2x^T(t-h)[P_{24}]x(t-\tau)$$

$$+2x^T(t-h)[P_{12}^T W_0]f(x(t)) + 2x^T(t-h)[P_{12}^T W_1]f(x(t-\tau))$$

$$+2x^T(t-h)[P_{12}^T W_2]\int_{t-r}^{t} f(x(s))ds$$

$$+2x^T(t-h)h[-P_{33} - L_1^T]x(s) + 2x^T(t-h)[\tau P_{34}]x(s)$$

$$+2x^T(t-h)[-hK_2^T - \frac{h^2}{2}L_2^T]\dot{x}(s) + 2\dot{x}^T(t-h)[-Q_2]\dot{x}(t-h)$$

$$+2\dot{x}^T(t-h)h[C^T P_{13} + P_{23}]x(s) + 2\dot{x}^T(t-h)\tau[C^T P_{14} + P_{24}]x(s)$$

$$+x^T(t-\tau)[-Q_3 - M_2^T - M_2]x(t-\tau)$$

$$+2x^T(t-\tau)h[-P_{34}^T]x(s) + 2x^T(t-\tau)\tau[-P_{44}^T - N_2^T]x(s)$$

$$+2x^T(t-\tau)[-\tau M_2^T - \tau^2 2N_2^T]\dot{x}(s)$$

$$+ f^T(x(t))[r^2 Q_8 + S]f(x(t))$$

$$++2f^T(x(t))h[W_0^T P_{13}]x(s) + 2f^T(x(t))\tau[W_0^T P_{14}]x(s)$$

$$+2f^T(x(t-\tau))[-S]f(x(t-\tau)) + 2f^T(x(t-\tau))h[W_1^T P_{13}]x(s)$$

$$+2f^T(x(t-\tau))\tau[W_1^T P_{14}]x(s)$$

$$+2\int_{t-r}^{t} f^T(x(s))ds[-Q_8]\int_{t-r}^{t} f(x(s))ds + \int_{t-r}^{t} f^T(x(s))h[W_2^T P_{13}]x(s)$$

$$+2\int_{t-r}^{t} f^T(x(s))ds\,\tau[W_2^T P_{14}]x(s)$$

$$+x^T(s)[-hQ_4]x(s) + x^T(s)[-\tau Q_5]x(s)$$

$$+\dot{x}^T(s)[-hQ_6]\dot{x}(s) + \dot{x}^T(s)[-\tau Q_7]\dot{x}(s)$$

$$+\dot{x}^T(t)[hQ_6+\tau Q_7+Q_2]\dot{x}(t). \quad (16)$$

Then $\dot{x}^T(t)[hQ_6+\tau Q_7+Q_2]\dot{x}(t)=0,$ sub into (19),

$$\dot{V}(t,x)\le \eta^T(t)\,\Xi^1\,\eta(t)+\eta^T(t)\,\Xi^2\,\eta(t). \quad (17)$$

$$\dot{V}(t,x)\le 0, \quad (18)$$

Where

$$\eta=\left[x^T(t)\ x^T(t-h)\ \dot{x}^T(t-h)\ x^T(t-\tau)\ f^T(x(t))\ f^T(x(t-\tau))\ \int_{t-r}^{t} f(x(s))ds\ x^T(s)\ \dot{x}^T(s)\right]^T$$

and thus according to Lyapunov stability theory, The nominal system (1) is asymptotically stable.

IV. Numerical Example

To illustrate the usefulness of the proposed approach, we present the following example.

Consider the following uncertain Neutral-type systems with the parameters as follows:

$$\dot{x}(t)=-Ax(t)+W_0 f(x(t))+W_1 f(x(t-\tau))+C\dot{x}(t-h)+W_2\int_{t-r}^{t} f(x(s))ds$$

,

$$A=\begin{bmatrix}-0.05 & 0\\ 0 & -1.8\end{bmatrix},\ W_0=\begin{bmatrix}-0.02 & 0\\ -0.05 & 1\end{bmatrix},$$

,

$$W_1=\begin{bmatrix}4 & 0.1\\ 0.2 & -0.03\end{bmatrix},\ W_2=\begin{bmatrix}-6.5 & 1\\ 0.2 & 0.1\end{bmatrix},$$

$$C=\begin{bmatrix}-1 & 1\\ 0.2 & 0.1\end{bmatrix},\ D=\begin{bmatrix}0.2 & 0\\ 0 & 0.2\end{bmatrix},$$

$$E_1=\begin{bmatrix}0.5 & 0\\ 0 & 0.5\end{bmatrix},\ E_3=\begin{bmatrix}0.5 & 0\\ 0 & 0.5\end{bmatrix},$$

,

$$E_4=\begin{bmatrix}0.5 & 0\\ 0 & 0.5\end{bmatrix}$$

$$E_5=\begin{bmatrix}0.5 & 0\\ 0 & 0.5\end{bmatrix},\ E_6=\begin{bmatrix}0.5 & 0\\ 0 & 0.5\end{bmatrix},$$

with $\varepsilon=0.35,\ h=0.01,\ \tau=0.02,\ r=0.01,$. Then by applying Theorem 3.1 in MATLAB LMI Toolbox the feasible solutions are

$$P_{11}=10^{-6}\begin{bmatrix}0.0466 & -0.1564\\ -0.1564 & 1.0949\end{bmatrix},$$

$$P_{12}=10^{-6}\begin{bmatrix}0.0333 & -0.0595\\ -0.0595 & 0.0542\end{bmatrix},$$

$$P_{13}=10^{-6}\begin{bmatrix}0.1476 & -0.0014\\ -0.0014 & 0.1363\end{bmatrix},$$

$$P_{14}=10^{-6}\begin{bmatrix}0.1562 & -0.0500\\ -0.0500 & 1.8133\end{bmatrix},$$

$$P_{22}=10^{-6}\begin{bmatrix}0.2785 & -0.3741\\ -0.3741 & 0.3.2018\end{bmatrix},$$

$$P_{23}=\begin{bmatrix}-0.1477 & -0.0004\\ -0.0004 & -0.1440\end{bmatrix}$$

$$P_{24}=10^{-6}\begin{bmatrix}5.4204 & -0.1904\\ -0.1904 & 5.7305\end{bmatrix},$$

$$P_{33}=10^{-6}\begin{bmatrix}0.3873 & -0.1851\\ -0.1851 & 3.8283\end{bmatrix}$$

$$P_{34}=10^{-6}\begin{bmatrix}0.7163 & -0.7828\\ -0.7828 & 9.9407\end{bmatrix},$$

$$P_{44}=10^{-6}\begin{bmatrix}4.1666 & 0\\ 0 & 4.1666\end{bmatrix}$$

$$Q_1=10^{-6}\begin{bmatrix}6.3798 & -0.0489\\ -0.0489 & 5.7799\end{bmatrix},$$

$$Q_2=\begin{bmatrix}0.0030 & -0.0023\\ -0.0023 & 0.0074\end{bmatrix},$$

$$Q_3 = 10^{-6}\begin{bmatrix} 1.4845 & 0.0155 \\ 0.0155 & 1.5291 \end{bmatrix},$$

$$Q_4 = \begin{bmatrix} 0.0138 & 0.0022 \\ 0.0022 & 0.0090 \end{bmatrix},$$

$$Q_5 = 10^{-6}\begin{bmatrix} 4.0398 & 0.0070 \\ 0.0070 & 4.0488 \end{bmatrix},$$

$$Q_6 = \begin{bmatrix} 0.0040 & -0.0433 \\ -0.0433 & 0.4208 \end{bmatrix}$$

$$Q_7 = \begin{bmatrix} 0.1262 & -0.9209 \\ -0.9209 & 7.0205 \end{bmatrix},$$

$$Q_8 = \begin{bmatrix} 5.2884 & 0.0101 \\ 0.0101 & 6.8036 \end{bmatrix}$$

Therefore the uncertain Neutral-type systems is asymptotically stable.

CONCLUSION

In this paper, by constructing an appropriate Lyapunove-Krasovskii functional, and employing the free-weighting matrices technique, some sufficient conditions ensuring the robustly stability for uncertain neutral-type systems are derived, Numerical examples are provided to illustrate the effectiveness of our obtained results.

REFERENCES

[1] Liu PL, Delay-dependent stabilization for linear time-delay uncertain systems with saturating actuators, Int. J. Gen. Syst. 40 (2011) 301 – 312.

[2] Liu PL, Robust stability for neutral time-varying delay systems with nonlinear perturbations, International journal of Innovative Computing, Information and Control 10 (7) (2011) 5749 – 5760.

[3] Fridman E, Shaked U, A descriptor system approach to control of linear time-delay systems, IEEE Trans. Automat. control 47 (2002) 253 – 270.

[4] Gao HJ, Wang CH, Delay-dependent robust and filtering for a class of uncertain nonlinear time-delay systems, IEEE Trans. Automat. Control 48 (9) (2003) 1661-1666.

[5] Peng C, Han QL, Yue D, Tian E, Sampled-data robust control for T–S fuzzy systems with time delay and uncertainties, Fuzzy Sets and Systems 179 (2011) 20 – 33.

[6] Peng C, Tian YC, Delay-dependent robust control for uncertain systems with time-varying delay. Inform. Sci. 179 (2009) 3187 – 3197.

[7] Wang JW, Wu HN, Guo L, Luo YS, Robust fuzzy control for uncertain nonlinear Markovian jump systems with time-varying delay, Fuzzy Sets and Systems 212 (2013) 41 – 61.

[8] Zhang H, Shen Y, Feng G, Delay-dependent stability and control for a class of fuzzy descriptor systems with time-delay, Fuzzy Sets and Systems 160 (2009) 1689 – 1707.

[9] Li X, Souza CED, Delay-dependent robust stability and stabilization of uncertain linear delay systems: a linear matrix inequality approach, IEEE Trans. Automat. Control 42 (1997) 1144 –1148.

[10] Li L, Liu X, New results on delay-dependent robust stability criteria of uncertain fuzzy systems with state and input delays, Inform. Sci. 179 (2009) 1134 – 1148.

[11] Y.Ariba, F.Gouaisbaut, Delay-dependet stability analysis of linera systems with time-varying delay, in:proceedings of the 46th IEEE Conference on Decision and control,New-Orleans, LA,USA, December 12-14,2007.

[12] P.Balasubramanian,A.Manivanan,R.Rakkiyappan, Delay-dependent stability of neutral systems with time-varying delays and markovian jump parameters, Appl.Math.comput 216 (2010) 3396-3407.

[13] P.Balasubramanian,R.Krishenasamy,R.Rakkiyappan, Delay-dependent stability of neutral system with time-varying delays using delays-decomposition approach, Appl.Math.Model. 36 (2012) 2253-2261.

[14] E.Fridman,U.Shaked, An improved stabilization method for linear time-delay systems, IEEE Trans.Automat.Contral 47 (2002) 1931-1937.

[15] K.Gu.Q.Han,A.Luo,S.Niculescu, Discretized Lyapunov functional for systems with distributed delay and piecewise costant coefficients, Int.J.Control 74 (2001) 737-744.

[16] Q.Han, A descriptor system approach to robust stability of neutral systems with discrete and distributed delay, Automatica 40 (2004) 1791-1796.

[17] T.Li,A.song,S.Fei,T.Wang, Delay-derivative-dependent stability for delayed neural networks with unbounded distributed delay IEEE Trans.Neural Net. 21 (2010) 1365-1371.

[18] T.Li,L.Guo,C.Lin, Stability criteria with less LMI variables for neural networks with time-varying delay, IEEE Tarn.Circuits syst.II:Express Briefs 55 (2008) 1188-1192.

[19] M.J.Park, O.M.Kwon,J.H.Park, S.M.Lee, A new ausmented Lyapunov-Krasovskii functional approach for stability of linear systems with time-varying delays, APPl.Math.Comput. 217 (2011) 7197-7209.

[20] W.Qian, J.Liu,S.Fei, Augmented Lyapunov functional approach for stability of neutral systems with mixed delays Asian J.Control 14 (2012) 1-8.

[21] Z.-G.Wu,J.Park, H.Su,J.Chu, Admissibility and dissipativity analysis for discrete-time singular systems with mixed time-varying delay Appl.Math. Comput. 218 (2012) 7128-7138.

[22] Z.-G.Wu,J.Park, H.Su,J.Chu, Dissipativity and analysis for singular system for singular systems with time-varying delays, Appl.Math.Comput. 218 (2011) 4605-4613.

[23] S.Xu,J.Lam, Improved delay-depedent stability criteria for time-delay systems, IEEE Trans. Automat.Control 50 (2005) 384-387.

[24] S.Xu,J.Lam, A survey of linear matrix inequality techniques in stability analysis of delay systems, Int.J.syst.Sci. 39 (2005) 384-387.

[25] S.Xu,J.Lam,M.Zhong, New exponential estimates for time-delay system, IEEE Tran,Automat.Control 51 (2006) 1501-1505.

[26] S.Xu,J.Lam, on equivalence and efficiency of certein stability criteria for time-delay systems, IEEE Tran,Automat.Control 52 (2007) 95-101.

[27] D.Yue,Q.Han, A delay-dependent stability criterion of neutral systems and its application to a apartial element equivalent circuit model, IEEE Trans.Circuit Syst. 51 (2004) 685-689.

[28] L.Zhang,P.shi, E.Boukas, A Haider,C.Wang, output-feedback contral for switched linear discrete-time system with-varying delays, Int.J.Control 80 (2007) 1354-1365.