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Parameter Fault Detection and Estimation for Neutral Jump Systems Using Filters*

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Abstract: The problem of fault detection and estimation for a class of markov neutral jump systems with time-delay and norm-bounded uncertainties is considered. By re-constructing the system, the dynamics of the overall augmented error systems is obtained which involves unknown inputs represented by disturbances, model uncertainty and time-delays. Both the conditions for the existence of the fault detection filter and roust fault detection filter are presented in terms of linear matrix inequalities. The proposed mode-dependent fault detection filter makes the systems have stochastically stability and has better ability of minimizing the effects of disturbances and enhancing the effects of faults to the residuals. Simulation results illustrate the effectiveness of the developed approaches.

Key words: markov neutral jump systems (MNJS); fault detection and estimation; filter; time-delay; uncertainties; linear matrix inequalities (LMIs)
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1　Introduction

Since the pioneering work on quadratic control of Markov jump systems in the mid 1960s, these systems regain increasing interest owing to the application of them being more comprehensive, for instance, economic systems, solar thermal receiver systems and communication systems etc. As a special class of hybrid systems, markov jump systems include two components which are the mode and the state in state vectors. The existing results about markov jump systems cover a great number of problems such as stochastic stability[1- 2], stochastic controllability[3], robust filtering[4] and references therein. Compared with these, however, very few literatures[5- 7] consider the fault detection problems for markov jump systems. As for the fault detection problems in [5- 7], it is worth noticing that some of them didn't consider the time-delay cases in Markov jump models, and while considered, the system time-delay is the retarded one which only contains time-delay in its states. In practice, the neutral time-delay systems which contains time-delay both in its states and in the derivatives of its states are frequently encountered in many dynamic systems and their presence must be taken into account in realistic design. Neutral systems often appear in the study of automatic control, circuit systems and population dynamics, etc, and many results[8- 9] have been presented.

In this paper, we discuss the problem of fault detection and estimation for a class of neutral jump system with

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time-delay and norm-bounded uncertainties. The augmented dynamic system is constructed based on the robust filter which parameters depend on the system mode. By selecting the appropriate Lyapunov-Krasovskii function, it gives the sufficient condition for the existence of the mode-dependent fault detection filter to the nominal system case and the system considering the time-delay and uncertainties case respectively. The design criterions are presented in the form of linear matrix inequalities (LMIs).

In the sequel, the following notion will be used: R^n and $R^{n\times m}$ denote dimensional Euclidean space, and the set of all the $n\times m$ real matrices, $\boldsymbol{A}^{\mathrm{T}}$ and $\boldsymbol{A}^{-1}$ denote the transpose and the inverse of any matrix or vector, diag $\{\boldsymbol{A},\boldsymbol{B}\}$ denotes the block-diagonal matrix of $\boldsymbol{A}$ and $\boldsymbol{B}$, $\|\cdot\|$ denotes the Euclidean norm of vectors, $\boldsymbol{E}\{\cdot\}$ denotes the mathematics statistical expectation of the stochastic process or vector, $L_2^n[0,+\infty)$ is the space of n-dimensional square integrable function vector over $[0,+\infty)$, $\boldsymbol{P}>0$ stands for a positive-definite matrix, $\boldsymbol{I}$ is the unit matrix with appropriate dimensions, "*" means the symmetric terms in a symmetric matrix.

2 System Description

Given a probability space $(\Omega, F, \boldsymbol{P})$ where Ω is the sample space, F is the algebra of events and $\boldsymbol{P}$ is the probability measure defined on F. Let the random form process $\{r_t, t\geqslant 0\}$ be the Markov stochastic process taking values on a finite set $\boldsymbol{M}=\{1,2,\cdots,N\}$ with transition rate matrix $\Pi=\{\pi_{ij}\}$, $i,j\in\boldsymbol{M}$ and define the following transition probability from mode i at time to mode j at time $t+\Delta t$ as

$$\boldsymbol{P}_{ij}=P_r\{\boldsymbol{r}_{t+\Delta t}=j\mid \boldsymbol{r}_t=i\}=\begin{cases}\pi_{ij}\Delta t+o(\Delta t) & i\neq j,\\ 1+\pi_{ij}\Delta t+o(\Delta t) & i=j,\end{cases}\tag{1}$$

with transition probability rates $\pi_{ij}\geqslant 0$ for $i,j\in\boldsymbol{M}$, $i\neq j$ and $\sum_{j=1,u\neq i}^{N}\pi_{ij}=-\pi_{ii}$ where $\Delta t>0$ and $\lim_{\Delta t\downarrow 0}\alpha(\Delta t)/\Delta t\rightarrow 0$.

Considering a class of continuous markov neutral jump system (MNJS) with time-delay and uncertainties over the space $(\Omega, F, \boldsymbol{P})$ by

$$\begin{cases}\dot{\boldsymbol{x}}(t)-\boldsymbol{J}(\boldsymbol{r}_t)\dot{\boldsymbol{x}}(t-d)=\boldsymbol{A}(\boldsymbol{r}_t)\boldsymbol{x}(t)+\boldsymbol{A}_d(\boldsymbol{r}_t)\boldsymbol{x}(t-d)+\boldsymbol{B}_d(\boldsymbol{r}_t)\boldsymbol{d}(t)+\boldsymbol{B}_f(\boldsymbol{r}_t)\boldsymbol{f}(t)+\\ \qquad g(\boldsymbol{x}(t),\boldsymbol{x}(t-d),\boldsymbol{d}(t),\boldsymbol{f}(t),i),\\ \boldsymbol{y}(t)=\boldsymbol{C}(\boldsymbol{r}_t)\boldsymbol{x}(t)+\boldsymbol{C}_d(\boldsymbol{r}_t)\boldsymbol{x}(t-d)+\boldsymbol{D}_d(\boldsymbol{r}_t)\boldsymbol{d}(t)+\boldsymbol{D}_f(\boldsymbol{r}_t)\boldsymbol{f}(t)+\\ \qquad h(\boldsymbol{x}(t),\boldsymbol{x}(t-d),\boldsymbol{d}(t),\boldsymbol{f}(t),i),\\ \boldsymbol{x}(t+\theta)=\phi(\theta)\qquad \theta\in[-d,0].\end{cases}\tag{2}$$

where $x(t)\in R^n$ is the state, $\boldsymbol{y}(t)\in R^l$ is the measured output, $\boldsymbol{d}(t)\in L_2^m[0,+\infty)$ is the unknown input, $\boldsymbol{f}(t)\in L_2^p[0,+\infty)$ is the fault to be detected, $h>0$ is the unknown delay constant, $g(\cdot)$, $h(\cdot)$ are norm-bounded uncertainties in the systems. $\phi(\theta)\in L_2[-d\quad 0]$ is a continuous vector-valued initial function. $\boldsymbol{J}(\boldsymbol{r}_t)$, $\boldsymbol{A}(\boldsymbol{r}_t)$, $\boldsymbol{A}_d(\boldsymbol{r}_t)$, $\boldsymbol{B}_d(\boldsymbol{r}_t)$, $\boldsymbol{B}_f(\boldsymbol{r}_t)$, $\boldsymbol{C}(\boldsymbol{r}_t)$, $\boldsymbol{C}_d(\boldsymbol{r}_t)$, $\boldsymbol{D}_d(\boldsymbol{r}_t)$, $\boldsymbol{D}_f(\boldsymbol{r}_t)$ are known mode-dependent constant matrices with appropriate dimensions. For notational simplicity, when $\boldsymbol{r}_t=i$, $i\in\boldsymbol{M}$, $\boldsymbol{J}(\boldsymbol{r}_t)$, $\boldsymbol{A}(\boldsymbol{r}_t)$, $\boldsymbol{A}_d(\boldsymbol{r}_t)$, $\boldsymbol{B}_d(\boldsymbol{r}_t)$, $\boldsymbol{B}_f(\boldsymbol{r}_t)$, $\boldsymbol{C}(\boldsymbol{r}_t)$, $\boldsymbol{C}_d(\boldsymbol{r}_t)$, $\boldsymbol{D}_d(\boldsymbol{r}_t)$, $\boldsymbol{D}_f(\boldsymbol{r}_t)$ are respectively denoted as $\boldsymbol{J}_i$, $\boldsymbol{A}_i$, $\boldsymbol{A}_{di}$, $\boldsymbol{B}_{di}$, $\boldsymbol{B}_{fi}$, $\boldsymbol{C}_i$, $\boldsymbol{C}_{di}$, $\boldsymbol{D}_{di}$, $\boldsymbol{D}_{fi}$. While without the uncertainties, i.e., $g(\cdot)=h(\cdot)\equiv 0$, system (2) is labeled as nominal MNJS.

Assumption 1 The matrices $\boldsymbol{J}_i$, $i\in\boldsymbol{M}$, satisfy $\boldsymbol{J}_i\neq 0$ and $\|\boldsymbol{J}_i\|<1$.

Assumption 2 The markov process is irreducible and system mode $\boldsymbol{r}_t$ is available at time t.

Assumption 3 For the sake of clarity, we consider that stochastic nonlinear MNJS (2) is supposed to be stochastically stable, $\boldsymbol{D}_{fi}$ is full rank matrix and $p\leqslant l$, and $[\boldsymbol{C}_i\quad \boldsymbol{A}_i]$ is supposed to be observable.

Definition 1 The nominal neutral jump system (2) (setting $\boldsymbol{d}(t),\boldsymbol{f}(t)\equiv 0$) is said to be stochastically stable, if for any initial $\boldsymbol{x}(t+\theta)=\phi(\theta)$ and mode $\boldsymbol{r}_0$, then

$$\lim_{T\to\infty}E\{\int_0^T\|\boldsymbol{x}(t,\phi(\theta),\boldsymbol{r}_0)\|^2\mathrm{d}t\mid \boldsymbol{r}_0,\boldsymbol{x}(t+\theta)=\phi(\theta),\theta\in[-d\quad 0]\}<\infty.\tag{3}$$

Definition 2[2] In the Euclidean space $\{R^n \times \boldsymbol{M} \times R_+\}$, we introduce the stochastic Lyapunov-Krasovskii function of system (2) as $\boldsymbol{V}(\boldsymbol{x}(t), \boldsymbol{r}_t = i, t > 0)$, the weak infinitesimal operator of which satisfies

$$\Gamma \boldsymbol{V}(\boldsymbol{x}(t), i) = \lim_{\Delta t \to 0}\frac{1}{\Delta t}[\boldsymbol{E}\{\boldsymbol{V}(\boldsymbol{x}(t+\Delta t), \boldsymbol{r}_{t+\Delta t}, t+\Delta t) \mid \boldsymbol{x}(t) = x, \boldsymbol{r}_t = i\} - \boldsymbol{V}(\boldsymbol{x}(t), i, t)] =$$
$$\frac{\partial}{\partial t}\boldsymbol{V}(\boldsymbol{x}(t), i, t) + \frac{\partial}{\partial \boldsymbol{x}}\boldsymbol{V}(\boldsymbol{x}(t), i, t)\dot{\boldsymbol{x}}(t, i) + \sum_{j=1}^{N}\pi_{ij}\boldsymbol{V}(\boldsymbol{x}(t), j, t). \tag{4}$$

As to system (2), we set up the following fault detection filter:

$$\begin{cases} \dot{\bar{\boldsymbol{x}}}(t) - \boldsymbol{J}_i\dot{\bar{\boldsymbol{x}}}(t-d) = \boldsymbol{A}_i\bar{\boldsymbol{x}}(t) + \boldsymbol{A}_{di}\bar{\boldsymbol{x}}(t-d) + \boldsymbol{H}_i[\boldsymbol{y}(t) - \bar{\boldsymbol{y}}(t)], \\ \bar{\boldsymbol{y}}(t) = \boldsymbol{C}_i\bar{\boldsymbol{x}}(t), \end{cases} \tag{5}$$

where $\bar{\boldsymbol{x}}(t) \in R^n$, $\bar{\boldsymbol{y}}(t) \in R^l$, are respectively represent the fault detection filter state and system output, and the mode-dependent matrix $\boldsymbol{H}_i$, $i \in \boldsymbol{M}$ is the unknown filter parameters to be designed.

Similar to literature[10-11], to design the fault detection filter $\boldsymbol{H}_i$, $i \in \boldsymbol{M}$, for the positive scalars γ and λ, we can propose the following performance index formulated from the viewpoint of L_2-gain for all non-zero $\boldsymbol{d}(t)$, $\boldsymbol{f}(t) \in L_2[0, \infty)$ and $T \to \infty$,

$$\boldsymbol{J}(T) = E\{\int_0^T \boldsymbol{r}^{\mathrm{T}}(t)r(t)\mathrm{d}t - \gamma^2\int_0^T \boldsymbol{d}^{\mathrm{T}}(t)\boldsymbol{d}(t)\mathrm{d}t - \lambda^2\int_0^T \boldsymbol{f}^{\mathrm{T}}(t)\boldsymbol{f}(t)\mathrm{d}t\} < 0 \qquad \lambda \to \min. \tag{6}$$

For model-based fault detection, the remaining important task for fault detection filter design is the evaluation of the generated residual. In order to detect the faults, the widely adopted approach is to choose an appropriate threshold J_{th} and determine the evaluation function $f(\boldsymbol{r})$. Under the assumption that unknown input d is L_2-norm bounded, the threshold J_{th} can be set as:

$$J_{th} = \sup_{d \in L_2, f = 0}\{\int_0^{t_0+\tau} r^{\mathrm{T}}(t)r(t)\mathrm{d}t\}. \tag{7}$$

The evaluation function is $f(r)$ determined by

$$f(r) = \int_0^{t_0+\tau}\boldsymbol{r}^{\mathrm{T}}(t)\boldsymbol{r}(t)\mathrm{d}t. \tag{8}$$

where $[t_0, t_0+\tau]$ is the finite-time window, τ denotes the length and t_0 denotes the initial evaluation time. The evaluation time window τ is limited because the evaluation of residual signal over the whole time range is impractical.

Therefore, the following logic can be made for fault detection

$$\begin{aligned} f(\boldsymbol{r}) \geqslant J_{th} &\to \text{with fault} \to \text{alarm}, \\ f(\boldsymbol{r}) < J_{th} &\to \text{no alarm (fault} \to \text{free)}. \end{aligned} \tag{9}$$

3 Robust Fault Detection for Time-delay Markov Neutral Jump System with Uncertain Parameters Case

In this section, we consider the robust fault detection filter design problems for MNJS (2) while considering the time-delay and uncertainties, which can be described as

$$\begin{cases} \boldsymbol{g}(\boldsymbol{x}(t), \boldsymbol{x}_d, \boldsymbol{d}(t), \boldsymbol{f}(t), i) = \Delta\boldsymbol{A}(t, i)\boldsymbol{x}(t) + \Delta\boldsymbol{A}_d(t, i)\boldsymbol{x}_d + \Delta\boldsymbol{B}_d(t, i)\boldsymbol{d}(t) + \Delta\boldsymbol{B}_f(t, i)\boldsymbol{f}(t), \\ \boldsymbol{h}(\boldsymbol{x}(t), \boldsymbol{x}_d, \boldsymbol{d}(t), \boldsymbol{f}(t), i) = \Delta\boldsymbol{C}(t, i)\boldsymbol{x}(t) + \Delta\boldsymbol{C}_d(t, i)\boldsymbol{x}_d + \Delta\boldsymbol{D}_d(t, i)\boldsymbol{d}(t) + \Delta\boldsymbol{D}_f(t, i)\boldsymbol{f}(t), \end{cases} \tag{10}$$

where

$$\begin{bmatrix} \Delta\boldsymbol{A}(t, i) & \Delta\boldsymbol{A}_d(t, i) & \Delta\boldsymbol{B}_d(t, i) & \Delta\boldsymbol{B}_f(t, i) \\ \Delta\boldsymbol{C}(t, i) & \Delta\boldsymbol{C}_d(t, i) & \Delta\boldsymbol{D}_d(t, i) & \Delta\boldsymbol{D}_f(t, i) \end{bmatrix} = \begin{bmatrix} \boldsymbol{M}_i \\ \boldsymbol{M}_{yi} \end{bmatrix}\boldsymbol{E}_i(t)[\boldsymbol{N}_i \quad \boldsymbol{N}_{yi} \quad \boldsymbol{N}_{di} \quad \boldsymbol{N}_{fi}], \tag{11}$$

where $\boldsymbol{M}_i$, $\boldsymbol{M}_{yi}$, $\boldsymbol{N}_i$, $\boldsymbol{N}_{yi}$, $\boldsymbol{N}_{di}$, $\boldsymbol{N}_{fi}$ are constant matrices of appropriate dimensions and $\boldsymbol{E}_i(t)$ is time-varying unknown matrix with Lebesgue measurable elements satisfying $\|\boldsymbol{E}_i(t)\| \leqslant 1$, $i \in \boldsymbol{M}$. In the sequel, do as previous section, letting $\Delta\boldsymbol{A}_i$, $\Delta\boldsymbol{A}_{di}$, $\Delta\boldsymbol{B}_{di}$, $\Delta\boldsymbol{B}_{fi}$, $\Delta\boldsymbol{C}_i$, $\Delta\boldsymbol{C}_{di}$, $\Delta\boldsymbol{D}_{di}$, $\Delta\boldsymbol{D}_{fi}$ and $\boldsymbol{E}_i$ represent $\Delta\boldsymbol{A}(i, t)$, $\Delta\boldsymbol{A}_d(i, t)$, $\Delta\boldsymbol{B}_d(t, i)$, $\Delta\boldsymbol{B}_f(t,$

$i)$, $\Delta C(i,t)$, $\Delta C_d(i,t)$, $\Delta D_d(i,t)$, $\Delta D_f(i,t)$ respectively.

Here, we set up the same filter (5), and define the state estimate error as $e(t)=x(t)-\bar{x}(t)$ and the output error as $r(t)=y(t)-\bar{y}(t)$ similarly, then the overall dynamic error system equation can be presented as follows:

$$\begin{cases}\dot{e}(t)-J_i\dot{e}_d=[A_i-H_iC_i]e(t)+A_{di}e_d+(\Delta A_i-H_i\Delta C_i)x(t)+[\Delta A_{di}-H_i(C_{di}+\Delta C_{di})]x_d+\\ \qquad [B_{di}+\Delta B_{di}-H_i(D_{di}+\Delta D_{di})]d(t)+[B_{fi}+\Delta B_{fi}-H_i(D_{fi}+\Delta D_{fi})]f(t),\\ r(t)=C_ie(t)+(C_{di}+\Delta C_{di})x_{li}+\Delta C_ix(t)+(D_{di}+\Delta D_{di})d(t)+(D_{fi}+\Delta D_{fi})f(t).\end{cases}\tag{12}$$

By defining $z(t)=[x^{\mathrm{T}}(t)\quad e^{\mathrm{T}}(t)]^{\mathrm{T}}$, and combining (2) and (12), the augmented system will be:

$$\begin{cases}\dot{z}(t)-\bar{J}_i\dot{z}(t-d)=\bar{A}_iz(t)+\bar{A}_{di}z(t-d)+\bar{B}_{di}d(t)+\bar{B}_{fi}f(t),\\ r(t)=\bar{C}_iz(t)+\bar{C}_{di}z(t-d)+\bar{D}_{di}d(t)+\bar{D}_{fi}f(t),\end{cases}\tag{13}$$

where

$$\bar{J}_i=\begin{bmatrix}J_i&0\\0&J_i\end{bmatrix};\ \bar{A}_i=\begin{bmatrix}A_i+\Delta A_i&0\\ \Delta A_i-H_i\Delta C_i&A_i-H_iC_i\end{bmatrix};\ \bar{A}_{di}=\begin{bmatrix}A_{di}+\Delta A_{di}&0\\ \Delta A_{di}-H_i(C_{di}+\Delta C_{di})&A_{di}\end{bmatrix};$$

$$\bar{B}_{di}=\begin{bmatrix}B_{di}+\Delta B_{di}\\ B_{di}+\Delta B_{di}-H_i(D_{di}+\Delta D_{di})\end{bmatrix};\ \bar{B}_{fi}=\begin{bmatrix}B_{fi}+\Delta B_{fi}\\ B_{fi}+\Delta B_{fi}-H_i(D_{fi}+\Delta D_{fi})\end{bmatrix};$$

$$\bar{C}_i=[\Delta C_i\quad C_i];\ \bar{C}_{di}=[C_{di}+\Delta C_{di}\quad 0];\ \bar{D}_{di}=D_{di}+\Delta D_{di};\ \bar{D}_{fi}=D_{fi}+\Delta D_{fi}.$$

Lemma 1[1] Stochastically stable means almost surely (asymptotically) stable.

Lemma 2 The nominal MNJS (2) is said to be stochastically stable, if there exist a set of mode-dependent positive-define symmetric matrices P_i, $i\in M$ and positive-define symmetric matrix Q, such that

$$\Pi_1=\begin{bmatrix}\bar{A}_i^{\mathrm{T}}P_i+P_i\bar{A}_i+Q+\sum_{j=1}^{N}\pi_{ij}P_j & P_iA_{di}-\bar{A}_i^{\mathrm{T}}P_iJ_i-\sum_{j=1}^{N}\pi_{ij}P_jJ_j\\ * & -A_{di}^{\mathrm{T}}P_iJ_i-J_i^{\mathrm{T}}P_iA_{di}-Q+\sum_{j=1}^{N}\pi_{ij}J_j^{\mathrm{T}}P_jJ_j\end{bmatrix}<0.\tag{14}$$

Lemma 3[9] Let T, U, F and V be real matrices of appropriate dimension with $T^{\mathrm{T}}F\leqslant I$, then for a scalar $\alpha>0$, we can get $T+UFV+V^{\mathrm{T}}F^{\mathrm{T}}U^{\mathrm{T}}\leqslant T+\alpha^{-1}UU^{\mathrm{T}}+\alpha V^{\mathrm{T}}V$.

Theorem 1 For the given scalars, MNJS (12) will be asymptotically stochastically stable, and for all non-zero $d(t)\in L_2[0,\infty)$, it satisfies inequality (6) while without considering the uncertainties, if there exist a set of mode-dependent symmetric positive-definite matrices P_i, $i\in M$, matrices $\bar{H}_i=P_iH_i$, $i\in M$ and symmetric positive-definite matrix Q, such that

$$\Pi_2=\begin{bmatrix}\phi_{11}&\phi_{12}&\phi_{13}&\phi_{14}&C_i^{\mathrm{T}}\\ *&\phi_{22}&\phi_{23}&\phi_{24}&0\\ *&*&-\gamma^2I&0&D_{di}^{\mathrm{T}}\\ *&*&*&-\lambda^2I&D_{fi}^{\mathrm{T}}\\ *&*&*&*&-I\end{bmatrix}<0,\tag{15}$$

where

$$\phi_{11}=A_i^{\mathrm{T}}P_i+P_iA_i-C_i^{\mathrm{T}}\bar{H}_i^{\mathrm{T}}-\bar{H}_iC_i+\sum_{j=1}^{N}\pi_{ij}P_j+Q,\ \phi_{13}=P_iB_{di}-\bar{H}_iD_{di},\ \phi_{14}=P_iB_{fi}-\bar{H}_iD_{fi},$$

$$\phi_{12}=P_iA_{di}-A_i^{\mathrm{T}}P_iJ_i-C_i^{\mathrm{T}}\bar{H}_i^{\mathrm{T}}J_i-\sum_{j=1}^{N}\pi_{ij}P_jJ_j,\ \phi_{22}=-A_{di}^{\mathrm{T}}P_iJ_i-J_i^{\mathrm{T}}P_iA_{di}-Q+\sum_{j=1}^{N}\pi_{ij}J_j^{\mathrm{T}}P_jJ_j,$$

$$\phi_{23}=-J_i^{\mathrm{T}}P_iB_{di}+J_i^{\mathrm{T}}\bar{H}_iD_{di},\ \phi_{24}=-J_i^{\mathrm{T}}P_iB_{fi}+J_i^{\mathrm{T}}\bar{H}_iD_{fi}.$$

Theorem 2 The MNJS (13) will be asymptotically stochastically stable, and for all non-zero $d(t)\in L_2[0,\infty)$, satisfy inequality (6), if there exist a set of mode-dependent symmetric positive-definite matrices $P_i=\mathrm{diag}\{R_i\ S_i\}$, $i\in M$, matrices $\bar{H}_i=S_iH_i$, $i\in M$, symmetric positive-definite matrix Q, and a positive scalar $\alpha>0$, such that

$$\min \rho$$

$$\text{subject to:}\begin{bmatrix} \varphi_{11} & \varphi_{12} & \varphi_{13} & \varphi_{14} & \varphi_{15} & \varphi_{16} \\ * & \varphi_{22} & \varphi_{23} & \varphi_{24} & \varphi_{25} & \varphi_{26} \\ * & * & \varphi_{33} & \alpha_i \boldsymbol{N}_{di}^{\mathrm{T}} \boldsymbol{N}_{fi} & \boldsymbol{D}_{di}^{\mathrm{T}} & 0 \\ * & * & * & \varphi_{44} & \boldsymbol{D}_{fi}^{\mathrm{T}} & 0 \\ * & * & * & * & -\boldsymbol{I} & \boldsymbol{M}_{yi} \\ * & * & * & * & * & -\alpha_i \boldsymbol{I} \end{bmatrix} < 0, \text{with } \rho = \lambda^2, \tag{16}$$

where

$$\varphi_{11} = \begin{bmatrix} \boldsymbol{A}_i^{\mathrm{T}} \boldsymbol{R}_i + \boldsymbol{R}_i \boldsymbol{A}_i + \sum_{j=1}^{N} \pi_{ij} \boldsymbol{R}_j + \alpha_i \boldsymbol{N}_i^{\mathrm{T}} \boldsymbol{N}_i & \boldsymbol{O} \\ \boldsymbol{O} & \boldsymbol{A}_i^{\mathrm{T}} \boldsymbol{S}_i + \boldsymbol{S}_i \boldsymbol{A}_i - \bar{\boldsymbol{H}}_i \boldsymbol{C}_i - \boldsymbol{C}_i^{\mathrm{T}} \bar{\boldsymbol{H}}_i^{\mathrm{T}} + \sum_{j=1}^{N} \pi_{ij} \boldsymbol{S}_j \end{bmatrix} + \boldsymbol{Q};$$

$$\varphi_{12} = \begin{bmatrix} \boldsymbol{R}_i \boldsymbol{A}_{di} - \boldsymbol{A}_i^{\mathrm{T}} \boldsymbol{R}_i \boldsymbol{J}_i - \sum_{j=1}^{N} \pi_{ij} \boldsymbol{R}_j \boldsymbol{J}_j + \alpha_i \boldsymbol{N}_i^{\mathrm{T}} \boldsymbol{N}_{yi} & \boldsymbol{O} \\ -\bar{\boldsymbol{H}}_i \boldsymbol{C}_{di} & \boldsymbol{S}_i \boldsymbol{A}_{di} - \boldsymbol{A}_i^{\mathrm{T}} \boldsymbol{S}_i \boldsymbol{J}_i - \boldsymbol{C}_i^{\mathrm{T}} \bar{\boldsymbol{H}}_i^{\mathrm{T}} - \sum_{j=1}^{N} \pi_{ij} \boldsymbol{S}_j \boldsymbol{J}_j \end{bmatrix};$$

$$\varphi_{13} = \begin{bmatrix} \boldsymbol{R}_i \boldsymbol{B}_{di} + \alpha_i \boldsymbol{N}_i^{\mathrm{T}} \boldsymbol{N}_{di} \\ \boldsymbol{S}_i \boldsymbol{B}_{di} - \bar{\boldsymbol{H}}_i \boldsymbol{D}_{di} \end{bmatrix}; \ \varphi_{14} = \begin{bmatrix} \boldsymbol{R}_i \boldsymbol{B}_{fi} + \alpha_i \boldsymbol{N}_i^{\mathrm{T}} \boldsymbol{N}_{fi} \\ \boldsymbol{S}_i \boldsymbol{B}_{fi} - \bar{\boldsymbol{H}}_i \boldsymbol{D}_{fi} \end{bmatrix}; \ \varphi_{15} = \begin{bmatrix} \boldsymbol{O} \\ \boldsymbol{C}_i^{\mathrm{T}} \end{bmatrix}; \ \varphi_{16} = \begin{bmatrix} \boldsymbol{R}_i \boldsymbol{M}_i \\ \boldsymbol{S}_i \boldsymbol{M}_i - \bar{\boldsymbol{H}}_i \boldsymbol{M}_{yi} \end{bmatrix};$$

$$\varphi_{22} = -\boldsymbol{Q} - \begin{bmatrix} \boldsymbol{A}_{di}^{\mathrm{T}} \boldsymbol{R}_i \boldsymbol{J}_i + \boldsymbol{J}_i^{\mathrm{T}} \boldsymbol{R}_i \boldsymbol{A}_{di} - \sum_{j=1}^{N} \pi_{ij} \boldsymbol{J}_j^{\mathrm{T}} \boldsymbol{P}_j \boldsymbol{J}_j + \alpha_i \boldsymbol{N}_{yi}^{\mathrm{T}} \boldsymbol{N}_{yi} & -\boldsymbol{C}_{di}^{\mathrm{T}} \bar{\boldsymbol{H}}_i^{\mathrm{T}} \boldsymbol{J}_i \\ * & \boldsymbol{A}_{di}^{\mathrm{T}} \boldsymbol{S}_i \boldsymbol{J}_i + \boldsymbol{J}_i^{\mathrm{T}} S_i A_{di} - \sum_{j=1}^{N} \pi_{ij} \boldsymbol{J}_j^{\mathrm{T}} \boldsymbol{S}_j \boldsymbol{J}_j \end{bmatrix};$$

$$\varphi_{23} = \begin{bmatrix} -\boldsymbol{J}_i^{\mathrm{T}} \boldsymbol{R}_i \boldsymbol{B}_{di} + \alpha_i \boldsymbol{N}_{yi}^{\mathrm{T}} \boldsymbol{N}_{di} \\ -\boldsymbol{J}_i^{\mathrm{T}} \boldsymbol{S}_i \boldsymbol{B}_{di} + \boldsymbol{J}_i^{\mathrm{T}} \bar{\boldsymbol{H}}_i \boldsymbol{D}_{di} \end{bmatrix}; \ \varphi_{24} = \begin{bmatrix} -\boldsymbol{J}_i^{T} \boldsymbol{R}_i \boldsymbol{B}_{fi} + \alpha_i \boldsymbol{N}_{yi}^{\mathrm{T}} \boldsymbol{N}_{fi} \\ -\boldsymbol{J}_i^{\mathrm{T}} \boldsymbol{S}_i \boldsymbol{B}_{fi} + \boldsymbol{J}_i^{\mathrm{T}} \bar{\boldsymbol{H}}_i \boldsymbol{D}_{fi} \end{bmatrix}; \ \varphi_{25} = \begin{bmatrix} \boldsymbol{C}_{di}^{\mathrm{T}} \\ \boldsymbol{O} \end{bmatrix};$$

$$\varphi_{26} = \begin{bmatrix} -\boldsymbol{J}_i^{\mathrm{T}} \boldsymbol{R}_i \boldsymbol{M}_i \\ -\boldsymbol{J}_i^{\mathrm{T}} \boldsymbol{S}_i \boldsymbol{M}_i + \boldsymbol{J}_i^{\mathrm{T}} \bar{\boldsymbol{H}}_i \boldsymbol{M}_{yi} \end{bmatrix}; \ \varphi_{33} = -\gamma^2 \boldsymbol{I} + \alpha_i \boldsymbol{N}_{di}^{\mathrm{T}} \boldsymbol{N}_{di}; \ \varphi_{44} = -\lambda^2 \boldsymbol{I} + \alpha_i \boldsymbol{N}_{fi}^{\mathrm{T}} \boldsymbol{N}_{fi}.$$

4 Numerical Example

Considering a class of time-delay and uncertain MNJS (2) with parameters given by:

Mode 1 $\boldsymbol{A}_1 = \begin{bmatrix} 1.2 & 2 \\ -2 & -3 \end{bmatrix}$, $\boldsymbol{A}_{d1} = \begin{bmatrix} -0.2 & 0.2 \\ -0.1 & -0.2 \end{bmatrix}$, $\boldsymbol{J}_1 = \begin{bmatrix} 0.02 & 0.01 \\ 0.01 & 0.02 \end{bmatrix}$, $\boldsymbol{B}_{d1} = \begin{bmatrix} 0.2 \\ -0.1 \end{bmatrix}$, $\boldsymbol{B}_{f1} = \begin{bmatrix} 0.2 \\ 0.1 \end{bmatrix}$, $\boldsymbol{C}_1 = [0.2 \quad 0.2]$, $\boldsymbol{C}_{d1} = [-0.1 \quad 0.15]$, $\boldsymbol{D}_{d1} = [-0.1]$, $\boldsymbol{D}_{f1} = [0.1]$, $\boldsymbol{M}_1 = \begin{bmatrix} 0 \\ -0.2 \end{bmatrix}$, $\boldsymbol{M}_{y1} = [0.2]$, $N_1 = [0.2 \quad 0.1]$, $\boldsymbol{N}_{y1} = [0.1 \quad 0.2]$, $\boldsymbol{N}_{d1} = [0.2]$, $\boldsymbol{N}_{f1} = [-0.1]$.

Mode 2 $\boldsymbol{A}_2 = \begin{bmatrix} -3.5 & -4 \\ 2 & -3 \end{bmatrix}$, $\boldsymbol{A}_{d2} = \begin{bmatrix} -0.2 & 0.3 \\ -0.1 & -0.3 \end{bmatrix}$, $\boldsymbol{J}_1 = \begin{bmatrix} 0.01 & 0.02 \\ 0.02 & 0.01 \end{bmatrix}$, $\boldsymbol{B}_{d2} = \begin{bmatrix} 0.1 \\ 0.1 \end{bmatrix}$, $\boldsymbol{B}_{f2} = \begin{bmatrix} -0.2 \\ 0.1 \end{bmatrix}$, $\boldsymbol{C}_2 = [-0.1 \quad 0.2]$, $\boldsymbol{C}_{d2} = [0.1 \quad 0.12]$, $\boldsymbol{D}_{d2} = [0.1]$, $\boldsymbol{D}_{f2} = [-0.2]$, $\boldsymbol{M}_2 = \begin{bmatrix} 0.1 \\ 0.1 \end{bmatrix}$, $\boldsymbol{M}_{y2} = [-0.1]$, $\boldsymbol{N}_2 = [0.1 \quad -0.1]$, $\boldsymbol{N}_{y2} = [0.2 \quad 0.1]$, $\boldsymbol{N}_{d2} = [-0.1]$, $\boldsymbol{N}_{f2} = [0.1]$.

The transition rate matrix is defined by $\Pi = \begin{bmatrix} -7 & 7 \\ 6 & -6 \end{bmatrix}$.

By solving the LMIs (16), we can get and the mode-dependent fault detection filter gain matrices are as follows:

$$\boldsymbol{H}_1=\begin{bmatrix}0.9669\\0.4467\end{bmatrix},\ \boldsymbol{H}_2=\begin{bmatrix}0.6554\\-0.2911\end{bmatrix}.$$

Suppose the fault signal $\boldsymbol{f}(t)$ is the unit square wave from the 8_{th} second to the 12_{th} second. The additional noise $d(t)$ is white noise (variance is 0.1), which is shown in Fig. 1. Fig. 2 gives the residual evaluation function (the fault case and the fault-free case).

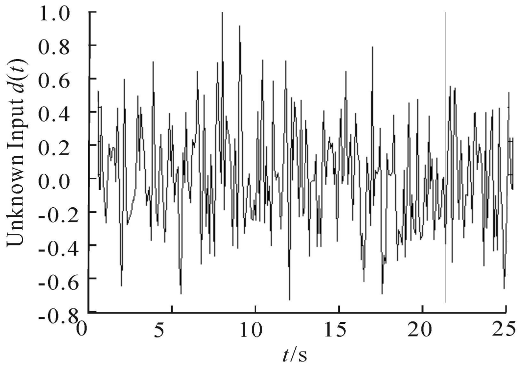

Fig. 1　Unknown Input $d(t)$

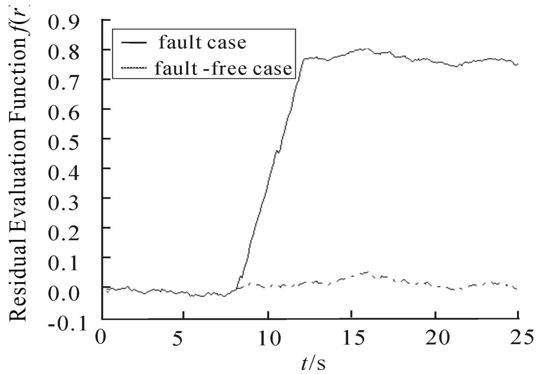

Fig. 2　Residual Evaluation Function $\boldsymbol{f}(\boldsymbol{r})$

With the selected threshold $J_{th} = \sup_{d\in L_2, f=0} E\{\int_0^{8.8} \boldsymbol{r}^{\mathrm{T}}(t)\boldsymbol{r}(t)\mathrm{d}t\} = 0.08$, Fig. 2 shows that $\boldsymbol{f}(\boldsymbol{r}) = E\{\int_0^{8.8} \boldsymbol{r}^{\mathrm{T}}(t)\boldsymbol{r}(t)\mathrm{d}t\} = 0.12 > J_{th}$. Thus, the appeared fault will be detected less than 1.0 second after its occurrence.

5　Conclusions

In the paper, we have addressed the design of fault detection filter in two cases for the markov neutral jump system (MNJS) with time-delays. It ensures asymptotically stable for the overall dynamic error system and a prescribed bound on the gain from the unknown noise to the estimation error. By selecting the appropriate Lyapunov-Krasovskii function and applying matrix transformation and variable substitution, the main results are provided in terms of LMIs form. Simulation example demonstrates the contribution of the main results.

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(下转第 71 页)

图 5　Change 函数

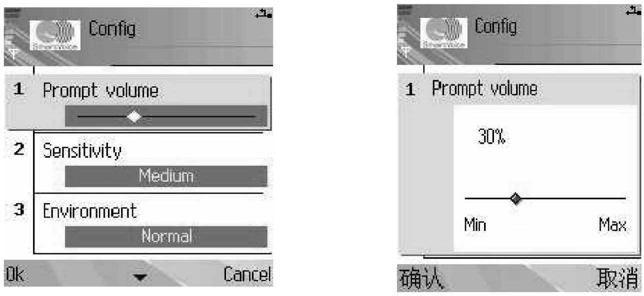

图 6　在手机上运行的效果

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The Implementation of User Interface of Voice Dialing Software on Smart-Phone Based on Symbian Operating System

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Abstract: Based on Symbian operating system, the user interface of voice dialing software on smart-phone is implemented in VC+ + 6.0 compiler environment. Through the software compiling and simulation with a simulator, the validity of the software design is tested. At last, when the software is down loaded to the mobile phone platform through Bluetooth and infrared format, the feasibility of the project is validated.

Key words: smart-phone; user interface; operating system

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(上接第 67 页)

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基于滤波器的中立跳变系统参数估计和故障检测

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摘　要: 研究了一类含时滞和不确定性的中立跳变系统的参数估计和故障检测问题, 通过重构系统, 获取了包括未知输入、模型不确定性和时滞的误差动态特性. 故障检测滤波器和鲁棒故障检测滤波器的存在条件都以线性矩阵不等式的形式给出. 所设计的受限于模态的故障检测滤波器使得系统随机稳定, 具有很好的抗扰性能和故障检测能力. 仿真示例说明了设计方法的有效性.

关键词: 中立跳变系统; 故障检测和估计; 滤波器; 时滞; 不确定性; 线性矩阵不等式.
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