Finite-Time Control for Markov Jump Systems with Partly Known Transition Probabilities and Time-Varying Polytopic Uncertainties

Chen Zheng[1], Xiaozheng Fan[1], Manfeng Hu[1,2],
Yongqing Yang[1,2], and Yinghua Jin[1,2]

[1] School of Science, Jiangnan University, Wuxi 214122, China
[2] Key Laboratory of Advanced Process Control for Light Industry (Ministry of Education), Jiangnan University, Wuxi 214122, China
ChenZ1208@126.com, fanxiaozhengjndx@sina.cn,
humanfeng@jiangnan.edu.cn, yongqingyang@163.com,
jyhmath@jiangnan.edu.cn

Abstract. In this paper, the finite-time control problem for Markov systems with partly known transition probabilities and polytopic uncertainties is investigated. The main result provided is a sufficient conditions for finite-time stabilization via state feedback controller, and a simpler case without controller is also considered, based on switched quadratic Lyapunov function approach. All conditions are shown in the form of LMIs. An illustrative example is presented to demonstrate the result.

Keywords: finite-time stabilization, Markov systems, polytopic uncertainties, partly known transition probabilities, linear matrix inequalities.

1 Introduction

Markov systems are modelled by a set of systems with the transitions between models governed by a Markov chain which takes values in a finite system set. The systems' evolutions in systems are determined by the transition probabilities. As pointed out in [1], the complete knowledge of the transition probabilities may be hard to measure. Therefore, it is of great importance to consider partly known transition probabilities. Some results are researched for Markov jump systems with partly known transition probabilities [2,3,4,5,6,7].

Finite-time stability means once we fix a time interval, its states does not exceed a certain bound over the time interval. In some cases, large values of the state are not acceptable [8]. The concept of finite-time stability has been revisited in the light of linear matrix inequalities and Lyapunov function theory [9,10,11,12,13,14,15]. To the best of our knowledge, the finite-time control for Markov jump systems with partly known transition probabilities has not been fully investigated yet.

Motivated by the above discussions, in this paper, the problem that the finite-time control for Markov jump systems with partly known transition probabilities

X. Hu et al. (Eds.): ISNN 2015, LNCS 9377, pp. 11–18, 2015.
DOI: 10.1007/978-3-319-25393-0_2

and time-varying polytopic uncertainties is investigated. Based on the switched quadratic Lyapunov function approach, a state feedback controller is designed. Further more, a corollary is given based on the main result, which is the sufficient condition for the simpler case of finite-time stability.

The superscript 'T' stands for matrix transposition, $E(\cdot)$ stands for the mathematical expectation. In symmetric block matrices or long matrix expressions, we use $*$ as an ellipsis for the terms that are introduced by symmetry. A matrix $P > 0$ (≥ 0) means P is a symmetric positive (semi-positive) definite matrix.

2 Problem Statement and Preliminaries

Consider the following discrete-time Markov jump linear system:

$$x(k+1) = A(r(k), \lambda)x(k) + B(r(k), \lambda)u(k) \tag{1}$$

where $x(k) \in R^n$ is the state vector, $u(k) \in R^m$ is the control input vector. $\{r(k), k \geq 0\}$ is a discrete-time Markov chain,which takes values in a finite set $\chi = \{1, 2, \ldots, N\}$ with a transition probabilities matrix $\Lambda = \{\pi_{ij}\}$, for $r(k) = i, r(k+1) = j$, one has $Pr(r(k+1) = j|r(k) = i) = \pi_{ij}$, where $\pi_{ij} \geq 0, \forall i, j \in \chi$, and $\sum_{j=1}^{N} \pi_{ij} = 1$. $N > 1$ is the number of subsystems, and we use $(A_i(\lambda), B_i(\lambda))$ denotes the ith system when $r(k) = i$. The transition probabilities of the jumping process $\{r(k), k \geq 0\}$ are assumed to be partially known. $\forall i \in \chi$, we denote

$$\chi_K^i = \{j : \pi_{ij} \ is\ known\} \ \chi_{UK}^i = \{j : \pi_{ij} \ is\ unknown\} \ . \tag{2}$$

The matrices of each subsystem have polytopic uncertain parameters. It is assumed that ,at each instant of time k, $(A_i(\lambda), B_i(\lambda)) \in R_i$, where R_i is a given convex bounded polyhedral domain described by

$$R_i = \{ \ (A_i(\lambda), B_i(\lambda)) = \sum_{m=1}^{s} \lambda_m (A_{i,m}, B_{i,m}) \ ; \ \sum_{m=1}^{s} \lambda_m = 1, \lambda_m \geq 0\} \quad i \in \chi \ , \tag{3}$$

where $(A_{i,m}, B_{i,m})$ denotes the mth vertex in the ith mode, s means the total number of vertices.

In this paper we derive a state feedback controller of the form $u(k) = K_i(\lambda)x(k)$, such that the Markov jump linear systems (1) is finite-time stabilizable. In particular we have the following definition and lemma.

Definition 1 (Finite-Time Stability [15]). *The discrete-time linear system (1) (setting $u(k) = 0$) is said to be finite-time stable with respect to $(\delta_x, \epsilon, R, N_0)$, where R is a positive-definite matrix, $0 < \delta_x < \epsilon$, if*

$$E(x^T(0)Rx(0)) \leq \delta_x^2 \Rightarrow E(x^T(k)Rx(k)) < \epsilon^2 \quad \forall k \in N_0 \ . \tag{4}$$

Remark 1. Systems that are Lyapunov asymptotically stable may not be finite-time stable. And the system (1) is said to be finite-time stabilizable if there exists a state feedback controller in the form of $u(k) = K_i(\lambda)x(k)$.

Lemma 1 (Schur Complement). *The linear matrix inequality*

$$S = \begin{bmatrix} S_{11} & S_{12} \\ S_{12}^T & S_{22} \end{bmatrix} < 0,$$

where $S_{11} = S_{11}^T$ *and* $S_{22} = S_{22}^T$ *are equivalent to*

$$S_{11} < 0,\ S_{22} - S_{12}^T S_{11}^{-1} S_{12} < 0\ . \tag{5}$$

3 Main Result

We consider the state feedback controller with the following structure:

$$u(k) = K_i(\lambda)x(k) \tag{6}$$

Theorem 1. *The Markov jump linear systems (1) is finite-time stabilizable with respect to* $(\delta_x, \epsilon, R, N_0)$ *if there exist a scalar* $\gamma \geq 1$*, positive scalars* $\phi_1,\ \phi_2$*, matrices* $S_{i,m} > 0$ *, matrices* $U_{i,m}$ $\forall i \in \chi,\ 1 \leq m < n \leq s$ *and* $\forall (i,j) \in (\chi \times \chi)$ *matrices*

$$\Omega_{m,n}^{i,j} = \begin{bmatrix} X_{m,n}^{i,j} & Y_{m,n}^{i,j} \\ W_{m,n}^{i,j} & Z_{m,n}^{i,j} \end{bmatrix}\ j \in \chi_{UK}^i,\ \ \Xi_{m,n}^{i,j} = \begin{bmatrix} D_{m,n}^{i,j} & E_{m,n}^{i,j} \\ F_{m,n}^{i,j} & G_{m,n}^{i,j} \end{bmatrix}\ j \in \chi_K^i,$$

satisfying $\forall (i,j) \in \chi \times \chi,\ (1 \leq m < n \leq s)$

$$\begin{bmatrix} -S_{j,m} - S_{j,n} - X_{m,n}^{i,j} - (X_{m,n}^{i,j})^T & S_{UK} \\ * & \nu \end{bmatrix} \leq 0,\ j \in \chi_{UK}^i, \tag{7}$$

$$\begin{bmatrix} -S_{K,m}^i - S_{K,n}^i - D_{m,n}^{i,j} - (D_{m,n}^{i,j})^T & S_K \\ * & \kappa \end{bmatrix} \leq 0,\ j \in \chi_K^i \tag{8}$$

$$\Omega^{i,j} = \begin{bmatrix} \Omega_1^{i,j} & \Omega_{1,2}^{i,j} & \cdots & \Omega_{1,s}^{i,j} \\ * & \Omega_2^{i,j} & \cdots & \Omega_{2,s}^{i,j} \\ \vdots & \vdots & \ddots & \vdots \\ * & * & \cdots & \Omega_s^{i,j} \end{bmatrix} < 0 \quad j \in \chi_{UK}^i, \tag{9}$$

$$\Xi^{i,j} = \begin{bmatrix} \Xi_1^{i,j} & \Xi_{1,2}^{i,j} & \cdots & \Xi_{1,s}^{i,j} \\ * & \Xi_2^{i,j} & \cdots & \Xi_{2,s}^{i,j} \\ \vdots & \vdots & \ddots & \vdots \\ * & * & \cdots & \Xi_s^{i,j} \end{bmatrix} < 0 \quad j \in \chi_K^i, \tag{10}$$

$$\phi_1 R < S_{i,m} < \phi_2 R\ , \tag{11}$$

$$\phi_2 \delta_x^2 < \epsilon^2 \phi_1 / \gamma^{N_0}\ , \tag{12}$$

where

$$\nu = -\gamma S_{i,m} - \gamma S_{i,n} - Z_{m,n}^{i,j} - (Z_{m,n}^{i,j})^T,$$

$$\kappa = (-\gamma \sum_{j\in\chi_K^i} \pi_{ij})(S_{i,m} + S_{i,n}) - G_{m,n}^{i,j} - (G_{m,n}^{i,j})^T,\ S_{K,n}^i = (\sum_{j\in\chi_K^i} \pi_{ij})S_{j,n},$$

$$\Omega_m^{i,j} = \begin{bmatrix} -S_{j,m} & A_{i,m}S_{i,m} + B_{i,m}U_{i,m} \\ * & -\gamma S_{i,m} \end{bmatrix} \quad j \in \chi_{UK}^i,$$

$$\Xi_m^{i,j} = \begin{bmatrix} -S_{K,m}^i & (\sum_{j\in\chi_K^i} \pi_{ij})(A_{i,m}S_{i,m} + B_{i,m}U_{i,m}) \\ * & -(\sum_{j\in\chi_K^i} \pi_{ij})\gamma S_{i,m} \end{bmatrix} \quad j \in \chi_K^i,$$

$$S_K = (\sum_{j\in\chi_K^i} \pi_{ij})(A_{i,n}S_{i,m} + A_{i,m}S_{i,n} + B_{i,n}U_{i,m} + B_{i,m}U_{i,n})$$

$$-E_{m,n}^{i,j} - (F_{m,n}^{i,j})^T,\ j \in \chi_K^i,$$

$$S_{UK} = A_{i,n}S_{i,m} + A_{i,m}S_{i,n} + B_{i,n}U_{i,m} + B_{i,m}U_{i,n} - Y_{m,n}^{i,j} - (W_{m,n}^{i,j})^T,\ j \in \chi_{UK}^i.$$

Furthermore, the state feedback controller can be represented as

$$K_i(\lambda) = U_i(\lambda)S_i(\lambda)^{-1}.$$

Proof. We choose the Lyapunov function $V(x(k)) = x(k)^T P_i(\lambda)x(k)$, and assume that $E(x^T(0)Rx(0)) \leq \delta_x^2$. Then we have

$$E(V(x(k+1))) - \gamma E(V(x(k))) = E\{x(k)^T[\widetilde{A}_i(\lambda)^T P_j(\lambda)\widetilde{A}_i(\lambda) - \gamma P_i(\lambda)]x(k)\}\ ,$$

where $\widetilde{A}_i(\lambda) = A_i(\lambda)+B_i(\lambda)K_i(\lambda)$, and the case $i = j$ denotes that the switched system is described by the ith system $\widetilde{A}_i(\lambda)$, and the case $i \neq j$ denotes that the system is being at the switching times from i to j. If

$$\widetilde{A}_i(\lambda)^T P_j(\lambda)\widetilde{A}_i(\lambda) - \gamma P_i(\lambda) < 0 \quad \forall(i,j) \in (\chi \times \chi)\ , \tag{13}$$

then we can obtain $E(V(x(k))) < \gamma^k E(V(x(0)))$.

Letting $S_{i,m} = P_{i,m}^{-1}$, $\widetilde{S}_{i,m} = R_m^{-1/2}S_{i,m}R_m^{-1/2}$, $\lambda_{sup} = sup\{\lambda_{max}(P_{i,m})\}$ and $\lambda_{inf} = inf\{\lambda_{min}(P_{i,m})\}$,we get

$$\gamma^k E(V(x(0))) \leq \gamma^k(1/\lambda_{inf})E(x(0)^T Rx(0)) \leq \gamma^{N_0}(1/\lambda_{inf})\delta_x^2\ ,$$

$$E(V(x(k))) = E(x(k)^T \Sigma_{m=1}^s \lambda_m P_{i,m}x(k)) \geq (1/\lambda_{sup})E(x(k)^T Rx(k))\ , \tag{14}$$

where $R = \sum_{m=1}^s \lambda_m R_m$, $\lambda_{max}(P_{i,m})$ *and* $\lambda_{min}(P_{i,m})$ mean the maximum and minimum eigenvalues. From (11), we can determine $\phi_1 \leq \lambda_{inf},\ \phi_2 \geq \lambda_{sup}$.

According to the above relations, we obtain

$$E(x(k)^T Rx(k)) < \phi_2/\phi_1\delta_x^2\gamma^{N_0}\ . \tag{15}$$

From (12), the finite-time stability of system (1) is guaranteed. So what we next do is to prove (13) holds.

By Lemma 1, multiplying both sides by diag $(P_j^{-1}(\lambda), P_i^{-1}(\lambda))$, changing the matrix variables with

$$S_i(\lambda) = P_i^{-1}(\lambda), \quad U_i(\lambda) = K_i(\lambda)P_i^{-1}(\lambda) \ , \tag{16}$$

and according to (3), multiplying by $\lambda_m, \lambda_n \geq 0$ summing up to s, we have

$$\begin{aligned}
\Psi = (\sum_{j\in\chi_{UK}^i} \pi_{ij} + \sum_{j\in\chi_K^i} \pi_{ij})\Psi = (\sum_{j\in\chi_{UK}^i} \pi_{ij})(\sum_{m=1}^{s} \lambda_m^2 \begin{bmatrix} -S_{j,m} & A_{i,m}S_{i,m} + B_{i,m}U_{i,m} \\ * & -\gamma S_{i,m} \end{bmatrix} \\
+\sum_{m=1}^{s-1}\sum_{n=m+1}^{s} \lambda_m\lambda_n \left\{ \begin{bmatrix} -S_{j,m} & A_{i,m}S_{i,n} + B_{i,m}U_{i,n} \\ * & -\gamma S_{i,n} \end{bmatrix} + \begin{bmatrix} -S_{j,n} & A_{i,n}S_{i,m} + B_{i,n}U_{i,m} \\ * & -\gamma S_{i,m} \end{bmatrix} \right\}) \\
+\sum_{m=1}^{s} \lambda_m^2 \begin{bmatrix} -S_{K,m}^i & (\sum_{j\in\chi_K^i} \pi_{ij})(A_{i,m}S_{i,m} + B_{i,m}U_{i,m}) \\ * & -\gamma(\sum_{j\in\chi_K^i} \pi_{ij})S_{i,m} \end{bmatrix} \\
+\sum_{m=1}^{s-1}\sum_{n=m+1}^{s} \lambda_m\lambda_n \{ \begin{bmatrix} -S_{K,m}^i & (\sum_{j\in\chi_K^i} \pi_{ij})(A_{i,m}S_{i,n} + B_{i,m}U_{i,n}) \\ * & -\gamma(\sum_{j\in\chi_K^i} \pi_{ij})S_{i,n} \end{bmatrix} \\
+ \begin{bmatrix} -S_{K,n}^i & (\sum_{j\in\chi_K^i} \pi_{ij})(A_{i,n}S_{i,m} + B_{i,n}U_{i,m}) \\ * & -\gamma(\sum_{j\in\chi_K^i} \pi_{ij})S_{i,m} \end{bmatrix} \} \ .
\end{aligned} \tag{17}$$

From (7),(8), we get

$$\Psi \leq \eta^T \Omega^{i,j} \eta + \eta^T \Xi^{i,j} \eta \ ,$$

where $\eta = [\lambda_1 I \ \lambda_2 I \ \cdots \ \lambda_s I]^T$. Therefore, $\Psi < 0$.

Conditions similar to those of Theorem 1 can be obtained for the case without controller.

Corollary 1. *The system* $x(k+1) = A(r(k),\lambda)x(k)$ *is finite-time stable with respect to* $(\delta_x, \epsilon, R, N_0)$ *if there exist a scalar* $\gamma \geq 1$*, matrices* $P_{i,m} > 0$ $\forall i \in \chi,\ 1 \leq m < n \leq s$ *and* $\forall (i,j) \in (\chi \times \chi)$ *matrices*

$$\Omega_{m,n}^{i,j} = \begin{bmatrix} X_{m,n}^{i,j} & Y_{m,n}^{i,j} \\ W_{m,n}^{i,j} & Z_{m,n}^{i,j} \end{bmatrix} \quad j \in \chi_{UK}^i, \ \ \Xi_{m,n}^{i,j} = \begin{bmatrix} D_{m,n}^{i,j} & E_{m,n}^{i,j} \\ F_{m,n}^{i,j} & G_{m,n}^{i,j} \end{bmatrix} \quad j \in \chi_K^i,$$

satisfying $\forall (i,j) \in \chi \times \chi,\ (1 \leq m < n \leq s)$

$$\begin{bmatrix} -P_{j,m} - P_{j,n} - X_{m,n}^{i,j} - (X_{m,n}^{i,j})^T & \overline{S}_{UK} \\ * & \overline{\nu} \end{bmatrix} \leq 0, \ j \in \chi_{UK}^i, \tag{18}$$

$$\begin{bmatrix} -P_{K,m}^i - P_{K,n}^i - D_{m,n}^{i,j} - (D_{m,n}^{i,j})^T & \overline{S}_K \\ * & \overline{\kappa} \end{bmatrix} \leq 0, \ j \in \chi_K^i, \tag{19}$$

$$\phi_1 R < P_{i,m} < \phi_2 R \ , \tag{20}$$

$$\Omega^{i,j} = \begin{bmatrix} \Omega_1^{i,j} & \Omega_{1,2}^{i,j} & \cdots & \Omega_{1,s}^{i,j} \\ * & \Omega_2^{i,j} & \cdots & \Omega_{2,s}^{i,j} \\ \vdots & \vdots & \ddots & \vdots \\ * & * & \cdots & \Omega_s^{i,j} \end{bmatrix} < 0 \quad j \in \chi_{UK}^i, \tag{21}$$

$$\Xi^{i,j} = \begin{bmatrix} \Xi_1^{i,j} & \Xi_{1,2}^{i,j} & \cdots & \Xi_{1,s}^{i,j} \\ * & \Xi_2^{i,j} & \cdots & \Xi_{2,s}^{i,j} \\ \vdots & \vdots & \ddots & \vdots \\ * & * & \cdots & \Xi_s^{i,j} \end{bmatrix} < 0 \quad j \in \chi_K^i, \tag{22}$$

where

$$\overline{S}_K = P_{K,m}^i A_{i,n} + P_{K,n}^i A_{i,m} - E_{m,n}^{i,j} - (F_{m,n}^{i,j})^T,$$

$$\overline{S}_{UK} = P_{j,m} A_{i,n} + P_{j,n} A_{i,m} - Y_{m,n}^{i,j} - (W_{m,n}^{i,j})^T,$$

$$\overline{\nu} = -\gamma P_{i,m} - \gamma P_{i,n} - Z_{m,n}^{i,j} - (Z_{m,n}^{i,j})^T,$$

$$\Omega_m^{i,j} = \begin{bmatrix} -P_{j,n} & P_{j,n} A_{i,m} \\ * & -\gamma P_{i,m} \end{bmatrix} \quad j \in \chi_{UK}^i,$$

$$\Xi_m^{i,j} = \begin{bmatrix} -P_{K,n}^i & P_{K,n}^i A_{i,m} \\ * & -(\sum_{j \in \chi_K^i} \pi_{ij}) \gamma P_{i,m} \end{bmatrix} \quad j \in \chi_K^i,$$

$$P_{K,n}^i = \sum_{j \in \chi_K^i} \pi_{ij} P_{j,n}, \ \overline{\kappa} = (-\gamma \sum_{j \in \chi_K^i} \pi_{i,j})(P_{i,m} + P_{i,n}) - G_{m,n}^{i,j} - (G_{m,n}^{i,j})^T.$$

4 Illustrative Example

Consider the system (1) , there are two vertices in each subsystem:

$$A_{11} = \begin{bmatrix} 1.413 & -0.652 \\ 0.280 & -0.605 \end{bmatrix}, A_{12} = \begin{bmatrix} -0.475 & 0.013 \\ 0.871 & 0.187 \end{bmatrix},$$

$$B_{11} = \begin{bmatrix} 0.243 & -0.351 \\ 1.286 & 0.92 \end{bmatrix}, B_{12} = \begin{bmatrix} -1.618 & 0.172 \\ -0.406 & -2.418 \end{bmatrix},$$

$$A_{21} = \begin{bmatrix} -1.350 & -0.814 \\ 1.524 & -1.217 \end{bmatrix}, A_{22} = \begin{bmatrix} 0.016 & -1.383 \\ 0.020 & -0.474 \end{bmatrix},$$

$$B_{21} = \begin{bmatrix} 0.165 & -1.642 \\ -0.111 & 1.364 \end{bmatrix}, B_{22} = \begin{bmatrix} -1.585 & -0.447 \\ -2.630 & 0.724 \end{bmatrix},$$

$$A_{31} = \begin{bmatrix} 0.121 & 0.736 \\ -1.496 & -0.73 \end{bmatrix}, A_{32} = \begin{bmatrix} 1.179 & 0.176 \\ 0.399 & -0.196 \end{bmatrix},$$

$$B_{31} = \begin{bmatrix} 0.572 & 0.663 \\ -0.428 & -0.985 \end{bmatrix}, B_{32} = \begin{bmatrix} -1.305 & -0.236 \\ -0.461 & 0.910 \end{bmatrix}.$$

The partly known transition probability matrix is given as follow:

$$\begin{bmatrix} 0.6 & ? & ? \\ ? & ? & 0.5 \\ ? & 0.2 & ? \end{bmatrix}.$$

According to Theorem 1, we assume $R = I,\ N_0 = 31,\ \phi_2 = 1,\ \delta_x^2 = 0.05,\ \epsilon = 8,\ \gamma = 1.04$. It can be seen from the figures that the system (1) with the controller $u(k) = K_i(\lambda)x(k)$ meets the specified requirement, where $K_i(\lambda) = U_i(\lambda)S_i(\lambda)^{-1}$.

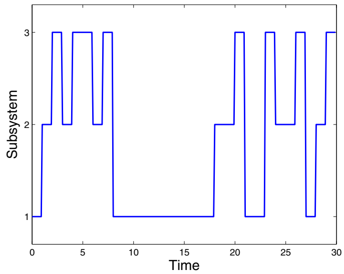

Fig. 1. The switching signal.

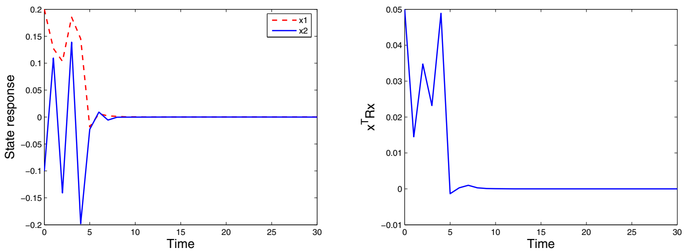

Fig. 2. The state response of system.

5 Conclusion

In this paper, the problem of finite-time stabilization for Markov jump linear systems with partly known transition probabilities and time-varying polytopic uncertainties has been studied. By using the switched quadratic Lyapunov function, all the conditions are established in the form of LMIs. At last, the main result has been demonstrated through an illustrative example.

References

1. Zhang, L., Boukas, E.K., Lam, J.: Analysis and synthesis of Markov jump linear systems with time-varying delays and partially known transition probabilities. IEEE Trans. Auto. Con. 53, 2458–2464 (2008)
2. Zhang, L., Boukas, E.K., Baron, L.: Fault detection for discrete-time Markov jump linear systems with partially known transition probabilities. Int. J. Con. 83, 1564–1572 (2010)
3. Braga, M.F., Morais, C.F., Oliveira, R.C.L.F.: Robust stability and stabilization of discrete-time Markov jump linear systems with partly unknown transition probability matrix. In: American Control Conference (ACC), pp. 6784–6789. IEEE Press, Washington (2013)
4. Tian, E., Yue, D., Wei, G.: Robust control for Markovian jump systems with partially known transition probabilities and nonlinearities. J. Fran. Ins. 350, 2069–2083 (2013)
5. Shen, M., Yang, G.H.: H_2 state feedback controller design for continuous Markov jump linear systems with partly known information. Inter. J. Sys. Sci. 43, 786–796 (2012)
6. Tian, J., Li, Y., Zhao, J.: Delay-dependent stochastic stability criteria for Markovian jumping neural networks with mode-dependent time-varying delays and partially known transition rates. Ap. Mathe. Com. 218, 5769–5781 (2012)
7. Rao, R., Zhong, S., Wang, X.: Delay-dependent exponential stability for Markovian jumping stochastic Cohen-Grossberg neural networks with p-Laplace diffusion and partially known transition rates via a differential inequality. Ad. Differ. Equa. 2013, 1–14 (2013)
8. Amato, F., Ariola, M., Dorato, P.: Finite-time control of linear systems subject to parametric uncertainties and disturbances. Auto. 37, 1459–1463 (2001)
9. Zhang, X., Feng, G., Sun, Y.: Finite-time stabilization by state feedback control for a class of time-varying nonlinear systems. Auto. 48, 499–504 (2012)
10. Hu, M., Cao, J., Hu, A.: A Novel Finite-Time Stability Criterion for Linear Discrete-Time Stochastic System with Applications to Consensus of Multi-Agent System. Cir. Sys. Sig. Pro. 34, 1–19 (2014)
11. Zhou, J., Xu, S., Shen, H.: Finite-time robust stochastic stability of uncertain stochastic delayed reaction-diffusion genetic regulatory networks. Neu. 74, 2790–2796 (2011)
12. Zuo, Z., Li, H., Wang, Y.: Finite-time stochastic stabilization for uncertain Markov jump systems subject to input constraint. Trans. Ins. Mea. Con. 36, 283–288 (2014)
13. Yin, Y., Liu, F., Shi, P.: Finite-time gain-scheduled control on stochastic bioreactor systems with partially known transition jump rates. Cir. Sys. Sig. Pro. 30, 609–627 (2011)
14. Bhat, S.P., Bernstein, D.S.: Continuous finite-time stabilization of the translational and rotational double integrators. IEEE Trans. Auto. Con. 43, 678–682 (1998)
15. Luan, X., Liu, F., Shi, P.: Neural-network-based finite-time H_∞ control for extended Markov jump nonlinear systems. Inter. J. Adap. Con. Sig. Pro. 24, 554–567 (2010)