É possível observar que as trajetórias de todos os estados convergem para zero, confirmando a solução do problema de controle. Ademais, os estados apresentam trajetórias não negativas, confirmando a positividade da malha fechada.

5. CONCLUSÃO

Este artigo apresentou novas condições na forma de LMIs para o projeto de controle por realimentação de estados para sistemas positivos chaveados discretos no tempo. A sequência de chaveamento não é conhecida a priori. Uma função de Lyapunov que faz uso de um vetor de estados aumentado contendo estados deslocados foi considerada, e o Lema de Finsler foi empregado na obtenção das condições. Foram propostas condições para projeto de controladores dependentes de modos e independentes de modos. Experimentos numéricos ilustraram a eficácia e o potencial da técnica apresentada. Como trabalhos futuros, os autores estão investigando o projeto de controle por realimentação de saída.

AGRADECIMENTOS

Agradecemos ao GCOM pelo suporte e à Prof. Cecília F. Morais pelas discussões.

REFERÊNCIAS

Boyd, S., El Ghaoui, L., Feron, E., and Balakrishnan, V. (1994). *Linear Matrix Inequalities in System and Control Theory*. SIAM Studies in Applied Mathematics, Philadelphia, PA.

Daafouz, J., Riedinger, P., and Iung, C. (2002). Stability analysis and control synthesis for switched systems: A switched Lyapunov function approach. *IEEE Transactions on Automatic Control*, 47(11), 1883–1887.

de Oliveira, M.C. and Skelton, R.E. (2001). Stability tests for constrained linear systems. In S.O. Reza Moheimani (ed.), *Perspectives in Robust Control*, volume 268 of *Lecture Notes in Control and Information Science*, 241–257. Springer-Verlag, New York, NY.

Deaecto, G.S. and Geromel, J.C. (2017). $\mathcal{H}_2$ state feedback control design of positive switched linear systems. In *Proceedings of the 20th IFAC World Congress*, 3136–3141. Toulouse, France.

Deaecto, G.S., Geromel, J.C., Garcia, F.S., and Pomilio, J.A. (2010). Switched affine systems control design with application to DC-DC converters. *IET Control Theory & Applications*, 4(7), 1201–1210.

Farina, L. and Rinaldi, S. (2000). *Positive Linear Systems: Theory and Applications*. John Wiley & Sons, New York, NY, USA.

Hernandez-Vargas, E., Colaneri, P., Middleton, R., and Blanchini, F. (2011). Discrete-time control for switched positive systems with application to mitigating viral escape. *International Journal of Robust and Nonlinear Control*, 21(10), 1093–1111.

Huang, J., Ma, X., Che, H., and Han, Z. (2020). Further Result on Interval Observer Design for Discrete-Time Switched Systems and Application to Circuit Systems. *IEEE Transactions on Circuits and Systems II: Express Briefs*, 67(11), 2542–2546.

Khalil, H.K. (2002). *Nonlinear Systems*. Prentice Hall, Upper Saddle River, NJ, 3rd edition.

Lacerda, M.J. and Seiler, P. (2017). Stability of uncertain systems using Lyapunov functions with non-monotonic terms. *Automatica*, 82, 187–193. doi:https://doi.org/10.1016/j.automatica.2017.04.042.

Lacerda, M.J. and Gomide, T.d.S. (2020). Stability and stabilisability of switched discrete-time systems based on structured Lyapunov functions. *IET Control Theory and Applications*, 14(5), 781–789.

Liu, T., Wu, B., Wang, Y.E., and Liu, L. (2017). New stabilization results for discrete-time positive switched systems with forward mode-dependent average dwell time. *Transactions of the Institute of Measurement and Control*, 39(2), 224–229.

Löfberg, J. (2004). YALMIP: A toolbox for modeling and optimization in MATLAB. In *Proceedings of the 2004 IEEE International Symposium on Computer Aided Control Systems Design*, 284–289. Taipei, Taiwan.

Pessim, P.S.P., Lacerda, M.J., and Agulhari, C.M. (2018). Parameter-dependent Lyapunov functions for robust performance of uncertain systems. In *Joint 9th IFAC Symposium on Robust Control Design and 2nd IFAC Workshop on Linear Parameter Varying Systems*, 441–446. Florianópolis, SC, Brazil.

Pessim, P.S.P., Leite, V.J.S., and Lacerda, M.J. (2019). Robust performance for uncertain systems via Lyapunov functions with higher order terms. *Journal of The Franklin Institute*, 356(5), 3139–3156.

Spagolla, A., Morais, C.F., Frezzatto, L., Oliveira, R.C.L.F., and Peres, P.L.D. (2018). Controle por realimentação de estados para sistemas lineares positivos chaveados discretos no tempo. In *Anais do XXII Congresso Brasileiro de Automática*, 1–6. João Pessoa, PB, Brasil.

Sturm, J.F. (1999). Using SeDuMi 1.02, a MATLAB toolbox for optimization over symmetric cones. *Optimization Methods and Software*, 11(1–4), 625–653. `http://sedumi.ie.lehigh.edu/`.

Tong, Y., Wang, C., and Zhang, L. (2012). Stabilisation of discrete-time switched positive linear systems via time- and state-dependent switching laws. *IET Control Theory & Applications*, 6(11), 1603.

Torikai, H. and Saito, T. (1998). Synchronization of chaos and its itinerancy from a network by occasional linear connection. *IEEE Transactions on Circuits and Systems I: Fundamental Theory and Applications*, 45(4), 464–472.

Zhang, L., Cui, N., Liu, M., and Zhao, Y. (2011). Asynchronous Filtering of Discrete-Time Switched. *IEEE Transactions on Circuits and Systems I: Regular Papers*, 58(5), 1109–1118.

Zhu, F. and Antsaklis, P.J. (2015). Optimal control of hybrid switched systems: A brief survey. *Discrete Event Dynamic Systems*, 25(3), 345–364.