Dynamics of Continuous, Discrete and Impulsive Systems
Series **B:** *Applications & Algorithms* **21 (2014)** 283-306

NONLINEAR CONTINUOUS-DISCRETE OBSERVER: APPLICATION TO A WASTEWATER TREATMENT PLANT

Othman BAKKA[1] and Fouad MESQUINE[1]

[1]Department of Physics
Cadi Ayyad University, Faculty of Sciences-Semlalia, P.O.Box 2390, Av. Pr. My. Abdellah, 40000, Marrakesh, Morocco

Corresponding Author: bakka.othman@gmail.com

Abstract. In this paper, a combination between a nonlinear continuous time dynamical model and discrete time output measurements has been investigated for estimating the unknown states. Assuming some persistent excitation conditions and the sampling steps to satisfy some boundedness hypotheses, system observability is ensured and consequently, guarantees the convergence of the continuous-discrete time observer synthesized in this work. The Lyapunov method is used to describe the stability analysis and for the observer synthesis. An application to wastewater treatment plant (WWTP) model is presented. Performances of the proposed approach are illustrated through numerical simulation.

Keywords. Software sensors; Nonlinear observer; Continuous-discrete time observer; Activated sludge; Wastewater treatment processes.

References

[1] Shen Yin, Hao Luo, Steven X. Ding. Real-time implementation of fault-tolerant control systems with performance optimization. IEEE transaction On Industrial Electronics. 2014; 61(5): 2402-2411.

[2] Steven X. Ding, Shen Yin, Kaixiang Peng, Haiyang Hao, Bo Shen. IEEE transaction On Industrial Informatics. A Novel Scheme for Key Performance Indicator Prediction and Diagnosis With Applicationto an Industrial Hot Strip Mill. 2013; 9(4): 2239-2247.

[3] Shen Yin, Steven X. Ding, Adel Haghani, Haiyang Hao, Ping Zhang. A comparison study of basic data-driven fault diagnosis and process monitoring methods on the benchmark Tennessee Eastman process. Journal of Process Control.2012; 22(9):1567-1581.

[4] Oscar A. Sotomayor Z, Song Won P, Claudio G. Software sensor for on-line estimation of the microbial activity in activated sludge systems. ISA Transaction 2002; 41: 127-143.

[5] Farza M, Hammouri H, Othman S, Busawon K. Nonlinear observers for parameter estimation in bioprocesses. Chemical Engineering Science 1997; 52(23): 4251-4267.

[6] Boulkroune B, Darouach M, Zasadzinski M, Gillé S, Fiorelli D. A nonlinear observer design for an activated sludge wastewater treatment process. Journal of Process Control 2009; 19: 1558-1565.

[7] Lafonta F, Busvelleb E, Gauthier JP. An adaptive high-gain observer for wastewater treatment systems. Journal of Process Control 2011; 21(6): 893-900.

[8] Mesquine F, Bakka O. Observer based regulator problem for WWT-P with constraints on the control. International Journal of Innovative Computing, Information and Control 2013; 9(2): 625-640.

[9] El bahja H, Vega P, Bakka O, Mesquine F. Modeling, estimation and optimal control design of a biological wastewater treatment process. 14th International Conference on Methods and Models in Automation and Robotics, Miedzyzdroje, Poland, 19 - 21 August, 2009.

[10] Mesquine F, Bakka O. El bahja H, Vega P. Observer based regulator problem for WWTP with constraints on the control. Emerging Technologies and Factory Automation. Bilbao, Spain, 13-16 Sept, 2010.

[11] Boutayeb M, Aubry D. A strong tracking extended Kalman observer for nonlinear discrete-time systems. IEEE Trans. on Automatic Control 1999; 44(8):1550-1556.

[12] Boutayeb M, Aubry D, Darouach M. Robust observers design for a class of nonlinear discrete-time systems. In Proceedings of the 4th European Control Conference , Bruxelle, Belgique, 1997.

[13] Gauthier JP, Hammouri H, Othman S. Observability for any u(t) of a class of bilinear systems . IEEE Trans. Automatic Control 1992; 37(6): 875-880.

[14] Farza M, Hammouri H, Jallut C, Lieto J. State observation of nonlinear systems : Application to (bio)Chemical Processes , AICHE 1999; 45: 93-106.

[15] Dalla Mora M, Germani A, Manes C. Design of state observer from a drift observability property , IEEE Trans Automatic Control 2000; 45: 1536-1540.

[16] Farza M, M'saad M, Rossignol L. Observer design for a class of MIMO nonlinear systems. IEEE Trans Automatic Control 2000; 40(1): 135-143.

[17] Alessandri A. Design of observers for lipschitz nonlinear systems using LMI. NOLCOS 2004; 2(9): 603-608.

[18] Zemouche A, Boutayeb M, Iulia Bara G. Observer design for nonlinear systems: an approach based on the differential mean value theorem. Proceedings of the 44th IEEE Conference on Decision and Control, and the European Control Conference, Seville, Spain, 2005.

[19] Nadri M., Hammouri H. Design of a continuous-discrete observer for state affine systems. Applied Mathematics Letters 2003; 16: 967-974.

[20] Moraal PE, Grizzle JW. Observer design for nonlinear systems with discrete-time measurements. IEEE Transactions on Automatic Control 1995; 40(3): 395-404.

[21] Bornard G, Celle F, Couenne N. Regularly persistent observers for bilinear systems. In Proc. of the 29th international conference on nonlinear systems, New trends in nonlinear systems theory 1988; 122: 130-140.

[22] Astorga CM, Othman N, Othman S, Hammouri H, Mckenna F. Nonlinear continuous-discrete observers: application to emulsion polymerization reactors. Control Engineering Practice 2002; 10: 3-13.

[23] Ouadi H, Giri F, Besancon G, Dugard L, Salhi B. Hybrid continuous-discrete state observer for induction machine in presence of magnetic saturation.In Proc of the 18th IFAC World Congress Milano (Italy) August 28 - September 2; 2011.

[24] Henze M, Leslie CP, Gujer GVR, Matsuo T. Activated Sludge Model no1 I.A.W.Q. Scientific and Technical Report No.1, Tech. rep., I.A.W.Q., London, UK, 1987.

[25] Smets I, Verdickt L, Van Impe JA. Linear ASM1 based multi-model for activated sludge systems. Mathematical and Computer Modeling of Dynamical Systems 2006; 12(5): 489-503.

[26] Gujer W, Henze M, Mino T, Matsuo T, Wentzel MC, Marais GVR. Basic concepts of the activated sludge model no 2: biological phosphorus removal process, in: IAWQ Specialized Seminar, Modelling and Control of Activated Sludge Processes, 1994.

[27] Gujer W, Henze M, Loosdrecht MV, Mino T. Activated sludge model no.3. Water Science and Technology 1999; 39(1): 183-193.

[28] Chachuat B, Roche N, Latifi MA. Reduction of the ASM1 model for optimal control of small-size activated sludge treatment plants. Rev. Sci. Eau 2003; 16: 5-26.

[29] Gildas Besan con. Book chapter: Nonlinear Observers and Applications. Editted by: Springer-Verlag Berlin Heidelberg 2007.

[30] Farza M, M'Saad M, Maatoug T, Koubaa Y. A set of adaptive observers for a class of MIMO nonlinear systems. Proceedings of the 44th IEEE Conference on Decision and Control, and the European Control Conference, Seville, Spain, December 12-15, 2005.

[31] S. Hadj Said, M.F. Mimouni, F. M'Sahli, M. Farza. High gain observer based on-line rotor and stator resistances estimation for IMs. Simulation Modelling Practice and Theory. vol (19), pp 1518-1529, 2011.

[32] Gauthier JP, Hammouri H, Othman S. A simple observer for nonlinear systems, applications to bioreactors. IEEE Transaction on Automatic Control 1992, 37(6):875-880.

[33] Olsson G, Newell B. Wastewater treatment systems. Modelling Diagnosis and Control, IWA Publishing, 1999.

[34] Alex J, Beteau JF , Copp JB, Hellinga C, Jeppsson U, Marsili-Libelli S, Pons MN, Spanjers H, Vanhooren H. Benchmark for evaluating control strategies in wastewater treatment plants, in: European Control Conference, Karlsruhe, Germany, 1999.

[35] A.M. Nagy Kiss, B. Marxa, G. Mourota, G. Schutzb, J. Ragota. Observers design for uncertain TakagiSugeno systems with unmeasurable premise variables and unknown inputs. Application to a wastewater treatment plant. Journal of Process Control 2011, 21 (7), 1105?114.

Received January 2014; revised November 2014.

email: journal@monotone.uwaterloo.ca
http://monotone.uwaterloo.ca/∼journal/

Appendix

Nomen -clature			
$X_{B,H}$	concentration of active heterotrophic biomass (mg/l)	i_{NXL}	mass of nitrogen in the inert particulate organic matter $(g_N g_{COD}^{-1})$
$X_{B,A}$	concentration of active autotrophic biomass (mg/l)	K_{La}	coefficient of oxygen rate (d^{-1})
X_{ND}	concentration of particulate biodegradable organic nitrogen (mg/l)	$K(.)$	half-saturation coefficient
X_S	concentration of particulate inert organic matter (mg/l)	$K_{NH,A}$	ammonia for autotrophs $(g_{NH} m^{-3})$
X_I	concentration of slowly biodegradable substrate (mg/l)	K_{NO}	nitrate for denitrifying heterotrophs $(g_{NO} m^{-3})$
S_{NO}	concentration of nitrate and nitrite nitrogen (mg/l)	$K_{O,A}$	oxygen for autotrophs $(g_{O_2} m^{-3})$
S_{NH}	concentration of ammonia nitrogen (mg/l)	$K_{O,H}$	oxygen for heterotrophs $(g_{O_2} m^{-3})$
S_{ND}	concentration of soluble biodegradable organic nitrogen (mg/l)	K_S	heterotrophic organisms $(g_{DCO} m^{-3})$
S_O^{sat}	dissolved oxygen saturation concentration (mg/l)	K_X	hydrolysis of slowly biodegradable substrate $(g_{DCO} g_{DCO}^{-1})$
S_I	concentration of soluble inert organic matter (mg/l)	Y_A	yield coefficient for autotrophic organisms
S_S	concentration of readily biodegradable substrate (mg/l)	Y_H	yield coefficient for heterotrophic organisms
S_O	concentration of dissolved oxygen (mg/l)	μ_A	maximum specific growth rate for autotrophic organisms (d^{-1})
b_A	decay rate coefficient for autotrophic organisms (d^{-1})	μ_H	maximum specific growth rate for heterotrophic organisms (d^{-1})
b_H	decay rate coefficient for heterotrophic organisms (d^{-1})	$\eta_{NO.g}$	correction factor for anoxic growth of heterotrophs
fr_{XI}	fraction of biomass generating the particulate products	$\eta_{NO.h}$	correction factor for anoxic hydrolysis
i_{NBM}	mass of nitrogen in the biomass $(g_N g_{COD}^{-1})$	V_O	the volume of the aeration tank (m^3)
D^{in}	influent flow rate $(m^3 d^{-1})$		