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Evolving Takagi-Sugeno Fuzzy Modeling Applications of Incremental Online Identification Algorithms

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Abstract – *This paper presents some of the results on the application of incremental online identification algorithms focused on the development of evolving Takagi-Sugeno fuzzy models and obtained by the Process Control group of the Politehnica University of Timisoara, Romania. The evolving Takagi-Sugeno fuzzy models describe the dynamics of four nonlinear dynamic systems specific to prosthetic hand fingers, crane systems, pendulum systems and twin rotor aerodynamic systems.*

Key words: crane systems, evolving Takagi-Sugeno fuzzy models, pendulum systems, prosthetic hand fingers, twin rotor aerodynamic systems

REFERENCES

[1] P. Angelov, *Evolving Rule based Models: A Tool for Design of Flexible Adaptive Systems*. Berlin, Heidelberg: Springer-Verlag, 2002.

[2] M. Sayed Mouchaweh, A. Devillez, G. Villermain Lecolier, and P. Billaudel, "Incremental learning in fuzzy pattern matching", *Fuzzy Sets and Systems*, vol. 132, no. 1, 49-62, Nov. 2002.

[3] P. X. Liu and M. Q.-H. Meng, "Online data-driven fuzzy clustering with applications to real-time robotic tracking", *IEEE Trans. Fuzzy Syst.*, vol. 12, no. 4, pp. 516-523, Aug. 2004.

[4] W. Wang and J. Vrbanek, Jr., "An evolving fuzzy predictor for industrial applications", *IEEE Trans. Fuzzy Syst.*, vol. 16, no. 6, pp. 1439-1449, Dec. 2008,

[5] E. Lughofer, *Evolving Fuzzy Systems - Methodologies, Advanced Concepts and Applications*. Berlin, Heidelberg: Springer-Verlag, 2011.

[6] D. Dovžan and I. Škrjanc, "Recursive clustering based on a Gustafson-Kessel algorithm", *Evolving Systems*, vol. 2, no. 1, pp. 15-24, March 2011.

[7] E. Lughofer, "On-line assurance of interpretability criteria in evolving fuzzy systems - achievements, new concepts and open issues", *Information Sciences*, vol. 251, pp, 22-46, Dec. 2013.

[8] R.-E. Precup, P. Angelov, B. S. J. Costa, and M. Sayed-Mouchaweh, "An overview on fault diagnosis and nature-inspired optimal control of industrial process applications", *Computers in Industry*, vol. 74, pp. 75-94, Dec. 2015.

[9] D. Dovžan, V. Logar, and I. Škrjanc, "Implementation of an evolving Fuzzy Model (eFuMo) in a monitoring system for a waste-water treatment process", *IEEE Trans. Fuzzy Syst.*, vol. 23, no. 5, pp. 1761-1776, Oct. 2015.

[10] J. Platt, "A resource allocating network for function interpolation", *Neural Computation*, vol. 3, no. 2, pp. 213-225, June 1991.

[11] C.-F. Juang and C.-T. Lin, "An on-line self-constructing neural fuzzy inference network and its applications", *IEEE Trans. Fuzzy Syst.*, vol. 6, no. 1, pp. 12-32, Feb. 1998.

[12] S. G. Tzafestas and K. C. Zikidis, "NeuroFAST: On-line neuro-fuzzy ART-based structure and parameter learning TSK model", *IEEE Trans. Syst., Man, Cybern. B, Cybern.*, vol. 31, no. 5, pp. 797-802, Oct. 2001.

[13] N. K. Kasabov and Q. Song, "DENFIS: Dynamic Evolving Neural-Fuzzy Inference System and its application for time-series prediction", *IEEE Trans. Fuzzy Syst.*, vol. 10, no. 2, pp. 144-154, Apr. 2002.

[14] F.-J. Lin, C.-H. Lin, and P.-H. Shen, "Self-constructing fuzzy neural network speed controller for permanent-magnet synchronous motor drive", *IEEE Trans. Fuzzy Syst.*, vol. 9, no. 5, pp, 751-759, Aug. 2002.

[15] P. Angelov and D. Filev, "An approach to online identification of Takagi-Sugeno fuzzy models", *IEEE Trans. Syst., Man, Cybern. B, Cybern.*, vol. 34, no. 1, pp. 484-498, Feb. 2004.

[16] E. Lughofer and E. P. Klement, "FLEXFIS: A variant for incremental learning of Takagi-Sugeno fuzzy systems", in *Proc. 14th IEEE International Conference on Fuzzy Systems*, Reno, NV, USA, 2005, pp. 915-920.

[17] M. Pratama, S. G. Anavatti, P. Angelov, and E. Lughofer, "PANFIS: A novel incremental learning machine", *IEEE Trans. Neural Netw. Learning Syst.*, vol. 25, no. 1, 55-68, Jan. 2014.

[18] R.-E. Precup, H.-I. Filip, M.-B. Radac, C. Pozna, C.-A. Dragos, and S. Preitl, "Experimental results of evolving Takagi-Sugeno fuzzy models for a nonlinear benchmark", in *Proc. 2012 IEEE 3rd International Conference on Cognitive Infocommunications*, Kosice, Slovakia, 2012, pp. 567-572.

[19] R.-E. Precup, H.-I. Filip, M.-B. Radac, E. M. Petriu, S. Preitl, and C.-A. Dragos, "Online identification of evolving Takagi-Sugeno-Kang fuzzy models for crane systems", *Applied Soft Computing*, vol. 24, pp. 1155-1163, Nov. 2014.

[20] R.-E. Precup, E.-I. Voisan, E. M. Petriu, M.-B. Radac, and L.-O. Fedorovici, "Implementation of evolving fuzzy models of a nonlinear process", in *Proc. 12th International Conference on Informatics in Control, Automation and Robotics*, Colmar, France, 2015, vol. 1, pp. 5-14.

[21] R.-E. Precup, E.-I. Voisan, E. M. Petriu, M.-B. Radac, and L.-O. Fedorovici, "Gravitational search algorithm-based evolving fuzzy models of a nonlinear process", in: *Informatics in Control, Automation and Robotics*, J. Filipe, K. Madani, O. Gusikhin, and J. Sasiadek, Eds. Cham: Springer International Publishing, Lecture Notes in Electrical Engineering, vol. 383, pp. 51-62, 2016.

[22] R.-E. Precup, T.-A. Teban, T. E. Alves de Oliveira, and E. M. Petriu, "Evolving fuzzy models for myoelectric-based control of a prosthetic hand", in *Proc. 2016 IEEE International Conference on Fuzzy Systems*, Vancouver, Canada, 2016, pp. 72-77.

[23] R.-E. Precup, M.-B. Radac, E. M. Petriu, R.-C. Roman, T.-A. Teban, and A.-I. Szedlak-Stinean, "Evolving fuzzy models for the position control of twin rotor aerodynamic systems", in *Proc. 2016 IEEE 14th International Conference on Industrial Informatics*, Poitiers, France, 2016, pp. 237-242.

[24] J. V. Ramos and A. Dourado, "On line interpretability by rule base simplification and reduction", in *Proc. European Symposium on Intelligent Technologies, Hybrid Systems and Their Implementation on Smart Adaptive Systems EUNITE 2004*, Aachen, Germany, 2004, pp. 1-6.

[25] L. Aires, J. Araújo, and A. Dourado, "Industrial monitoring by evolving fuzzy systems", in *Proc. Joint 2009 IFSA World Congress and 2009 EUSFLAT Conference*, Lisbon, Portugal, 2009, pp. 1358-1363.

[26] R.-E. Precup, R.-C. David, E. M. Petriu, S. Preitl, and M.-B. Radac, "Gravitational search algorithms in fuzzy control systems tuning", in *Proc. 18th IFAC World Congress*, Milano, Italy, 2011, pp. 13624-13629

[27] R.-E. Precup, R.-C. David, E. M. Petriu, S. Preitl, and M.-B. Radac, "Fuzzy logic-based adaptive gravitational search algorithm for optimal tuning of fuzzy controlled servo systems" *IET Control Theory & Applications*, vol. 7, no. 1, pp. 99-107, Jan. 2013.

[28] R.-C. David, R.-E. Precup, E. M. Petriu, M.-B. Radac, and S. Preitl, "Gravitational search algorithm-based design of fuzzy control systems with a reduced parametric sensitivity", *Information Sciences*, vol. 247, pp. 154-173, Oct. 2013.

[29] A. Turnau, A. Pilat, K. Hajduk, A. Korytowski, W. Grega, P. Gorczyca, K. Kolek, and M. Rosól, *Pendulum-Cart System User's Manual*. Krakow: INTECO Ltd., 2008.

[30] *Two Rotor Aerodynamical System, User's Manual.* Krakow, Poland: Inteco Ltd., 2007.

[31] S. Preitl and R.-E. Precup, "On the algorithmic design of a class of control systems based on providing the symmetry of open-loop Bode plots", *Scientific Bulletin of UPT, Transactions on Automatic Control and Computer Science*, vol. 41 (55), no. 2, pp. 47-55, Dec. 1996.

[32] R.-E. Precup and S. Preitl, "Popov-type stability analysis method for fuzzy control systems", in *Proc. Fifth European Congress on Intelligent Technologies and Soft Computing*, Aachen, Germany, 1997, vol. 2, pp. 1306-1310.

[33] P. Baranyi, "TP model transformation as a way to LMI-based controller design", *IEEE Trans. Ind. Electron.*, vol. 51, no. 2, pp. 387-400, Apr. 2004.

[34] G. Jovanović, D. Mitić, and M. K. Stojčev, "An adaptive pulse-width control loop", *International Journal of Electronics*, vol. 93, mo. 5, pp. 291-311, Oct. 2006.

[35] I. Škrjanc, S. Blažič, and O.E. Agamennoni, "Identification of dynamical systems with a robust interval fuzzy model", *Automatica*, vol. 41, no. 2, pp. 327-332, Feb. 2005.

[36] F. G. Filip, "Decision support and control for large-scale complex systems", *Annual Reviews in Control*, vol. 32, no. 1, pp. 61-70, Apr. 2008.

[37] B. Danković, S. Nikolić, M. Milojković, and Z. Jovanović, "A class of almost orthogonal filters", *Journal of Circuits, Systems, and Computers*, vol. 18, no. 5, pp. 923-931, Aug. 2009.

[38] J. Vaščák, "Approaches in adaptation of fuzzy cognitive maps for navigation purposes", in *Proc. 8th International Symposium on Applied Machine Intelligence and Informatics*, Herľany, Slovakia, 2010, pp. 31-36.

[39] A. Gajate, R. E. Haber, P. I. Vega, and J. R. Alique, "A transductive neuro-fuzzy controller: Application to a drilling process", *IEEE Trans. Neural Netw.*, vol. 21, no. 7, pp. 1158-1167, Jul. 2010.

[40] D. Antić, S. Nikolić, M. Milojković, N. Danković, Z. Jovanović, and S. Perić, "Sensitivity analysis of imperfect systems using almost orthogonal filters", *Acta Polytechnica Hungarica*, vol. 8, no. 6, pp. 79-94, Dec. 2011.

[41] R.-E. Precup, M.-B. Radac, M. L. Tomescu, E. M. Petriu, and S. Preitl, "Stable and convergent iterative feedback tuning of fuzzy controllers for discrete-time SISO systems", *Expert Systems with Applications*, vol. 40, no. 1, pp. 188-199, Jan. 2013.

[42] K. Lamár and A. G. Kocsis, "Implementation of brushed DC motor control in LabVIEW FPGA", *Carpathian Journal of Electronic and Computer Engineering*, vol. 6, no. 2, pp. 32-37, Dec. 2013.

[43] M.-B. Radac, R.-E. Precup, E. M. Petriu, S. Preitl, and C.-A. Dragos, "Data-driven reference trajectory tracking algorithm and experimental validation", *IEEE Trans. Ind. Informat.*, vol. 9, no. 4, pp. 2327-2336, Nov. 2013.