R.-E. Precup, Evolving Fuzzy Models and Transportation Applications, International Semiconductor Conference CAS 2024, Sinaia, Romania, 2024.

Evolving Fuzzy Models and Transportation Applications

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INVITED PRESENTATION

***Abstract*—As specified in the classic papers on evolving fuzzy systems due to Angelov and his co-authors back in 2001 and 2002, a specific feature of evolving fuzzy models in their either Mamdani or (Takagi-Sugeno or Takagi-Sugeno-Kang fuzzy) forms is the continuous online learning of the rule base. These fuzzy models are derived by online identification algorithms. The online identification algorithms continuously evolve the parameters in different subsystems of the fuzzy models, which are built online by adding new or removing old so-called "local" models. The local models are placed in the rule consequents, and this process is referred to as the adding mechanism.**

The well-recognized classification of online identification algorithms by Dovžan, Logar, and Škrjanc in 2015 highlights three representative families of online identification algorithms, (i), (ii), and (iii): (i) adaptive algorithms – which start from the initial Takagi-Sugeno-Kang fuzzy model structure given by other algorithms (i.e., (ii) incremental algorithms – which implement adding mechanisms; (iii) evolving algorithms – these are the most advanced and fresh ones, as they implement, besides the adding mechanism, also removing and a part of them merging and splitting mechanisms.

The operating mechanisms of online identification algorithms briefly described above give valid explanations on the rather large area of nonlinear systems whose behavior is characterized in order to ensure both accurate modeling for simulation and model-based fuzzy control design. The scope of the development of these models is the model-based and data-driven model-free design and tuning of fuzzy controllers by the Process Control Group of the Politehnica University of Timisoara, Romania.

This presentation focuses on some of the results obtained by the Process Control Group in applications of evolving fuzzy models. The presentation covers some representative and recent applications implemented in the group's laboratories, with real-world validation through experiments and detailed simulations. The results exemplified in this presentation concern several transportation applications, including the speed control of Connected Autonomous Electric Buses, taking into account the presence of human-driven vehicles, the anti-lock braking systems, and several servo systems.

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***Keywords*—evolving fuzzy models, incremental algorithms, Takagi-Sugeno-Kang fuzzy models, transportation applications**

SHORT BIO

Radu-Emil Precup (M IEEE '03 - SM IEEE '07) was born in Lugoj, Romania, in 1963. He received the Dipl.Ing. (Hons.) degree in automation and computers from the "Traian Vuia" Polytechnic Institute of Timisoara, Timisoara, Romania, in 1987, the Diploma in mathematics from the West University of Timisoara, Timisoara, in 1993, and the Ph.D. degree in automatic systems from the "Politehnica" University of Timisoara, Timisoara, in 1996.

From 1987 to 1991, he was with Infoservice S.A., Timisoara. He is currently with the Politehnica University of Timisoara, Romania, where he became a Professor in the Department of Automation and Applied Informatics, in 2000, and he is currently a Doctoral Supervisor of automation and systems engineering. From 2022, he is also a senior researcher (CS I) and the head of the Data Science and Engineering Laboratory of the Center for Fundamental and Advanced Technical Research, Romanian Academy – Timisoara Branch, Romania. From 2016 to 2022, he was an Adjunct Professor within the School of Engineering, Edith Cowan University, Joondalup, WA, Australia. He is currently the Director of the Automatic Systems Engineering Research Centre with the Politehnica University of Timisoara, Romania. From 1999 to 2009, he held research and teaching positions with the Université de Savoie, Chambéry and Annecy, France, Budapest Tech Polytechnical Institution, Budapest, Hungary, Vienna University of Technology, Vienna, Austria, and Budapest University of Technology and Economics, Budapest, Hungary. He is an editorial board member of several prestigious journals including IEEE Transactions on Fuzzy Systems, IEEE Transactions on Cybernetics, Information Sciences (Elsevier), Engineering Applications of Artificial Intelligence (Elsevier), Applied Soft Computing (Elsevier), Expert Systems with Applications (Elsevier), Evolving Systems (Springer), Applied Artificial Intelligence (Taylor & Francis), Healthcare Analytics (Elsevier), and Communications in Transportation Research (Elsevier).

He is the author or coauthor of more than 300 papers published in various scientific journals, refereed conference proceedings, and contributions to books. His research interests include mainly development and analysis of new control structures and algorithms (conventional control,

fuzzy control, data-based control, sliding mode control, neuro-fuzzy control, etc.), theory and applications of soft computing, computer-aided design of control systems, modeling, optimization (including nature-inspired algorithms), and applications to mechatronic systems (including automotive systems and mobile robots), embedded systems, control of power plants, servo systems, electrical driving systems.

Prof. Precup is a corresponding member of The Romanian Academy, a Doctor Honoris Causa of the Óbuda University, Budapest, Hungary, a Doctor Honoris Causa of the Széchenyi István University, Győr, Hungary, a member of the Task Force on Autonomous Learning Systems within the Neural Networks Technical Committee (TC) of the Institute of Electrical and Electronics Engineers (IEEE) Computational Intelligence Society, the TCs on Computational Cybernetics, and Cyber-Medical Systems of the IEEE Systems, Man, and Cybernetics Society, the Task Force on Adaptive and Evolving Fuzzy Systems within the Fuzzy Systems TC of the IEEE Computational Intelligence Society, the TCs on Data-Driven Control and Monitoring, and Control, Robotics and Mechatronics of the IEEE Industrial Electronics Society, the International Federation of Automatic Control (IFAC) TC on Computational Intelligence in Control (previously named Cognition and Control), the IFAC TC on Linear Control Systems, the Working Group WG 12.9 on Computational Intelligence of the Technical Committee TC12 on Artificial Intelligence of the International Federation for Information Processing (IFIP), the European Society for Fuzzy Logic and Technology (EUSFLAT), the Hungarian Fuzzy Association, and the Romanian Society of Control Engineering and Technical Informatics. He founded in 2015 and is the chair of the IEEE Systems, Man, and Cybernetics Society Romania Chapter. He has been the chair of the Timisoara Branch of the Robotics Society of Romania since 2020.

He was the recipient of the Elsevier Scopus Award for Excellence in Global Contribution (2017), the "Tudor Tănăsescu" Prize from the Romanian Academy for data-driven controller tuning techniques (2020), the "Grigore Moisil" Prize from the Romanian Academy, two times, in 2005 and 2016, for his contribution on fuzzy control and the optimization of fuzzy systems, the Spiru Haret Award from the National Grand Lodge of Romania in partnership with the Romanian Academy in 2016 for education, environment and IT, the Excellency Diploma of the International Conference on Automation, Quality & Testing, Robotics AQTR 2004 (THETA 14, Cluj-Napoca, Romania), two Best Paper Awards in the Intelligent Control Area of the 2008 Conference on Human System Interaction HSI 2008, Krakow (Poland), the Best Paper Award of 16th Online World Conference on Soft Computing in Industrial Applications WSC16 (Loughborough University, UK) in 2011, the Certificate of Appreciation for the Best Paper in the Session TT07 1 Control Theory of 39th Annual Conference of the IEEE Industrial Electronics Society IECON 2013 (Vienna, Austria), a Best Paper Nomination at 12th International Conference on Informatics in Control, Automation and Robotics ICINCO 2015 (Colmar, France), a Best Paper Award at 7th International Conference on Information Technology and Quantitative Management ITQM 2019 (Granada, Spain), a Best Paper Award at 8th International Conference on Information Technology and Quantitative Management ITQM 2020 & 2021 (Chengu, China), was named a 2022 academic data leader by Chief Data Officer (CDO) Magazine, and was listed as one of the top 10 researchers in Artificial Intelligence and Automation (according to IIoT World as of July 2017).

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