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Two-degree-of-freedom Fuzzy Controllers for Servo Systems in Transportation Applications

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KEYNOTE SPEECH

***Abstract*—Inspired by the 50th anniversary of the first fuzzy paper by Prof. László T. Kóczy and the 60th anniversary of the seminal fuzzy paper by Prof. Lotfi A. Zadeh, this paper covers issues related to the design, tuning, and implementation of two-degree-of-freedom (2-DOF) fuzzy controllers, focusing on 2-DOF Proportional-Integral fuzzy controllers and 2-DOF Proportional-Integral-Derivative fuzzy controllers in their Mamdani and Takagi-Sugeno-Kang forms. Tuning is based on mapping the parameters of the linear PI and PID controllers to the parameters of the fuzzy controllers in terms of the modal equivalence principle of Galichet and Foulloy (1995). The linear controllers are tuned by the Extended Symmetric Optimum method of Preitl and Precup (1999). The classical algebraic approach based on Diophantine equations and the mapping of the parameters of the 2-DOF linear controllers to the parameters of the 2-DOF fuzzy controllers are also treated. Nature-inspired optimization algorithm-based tuning of fuzzy controllers and their stable design are also covered. The controlled processes are servo systems and transportation applications are mentioned.**

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Keywords—2-DOF fuzzy controllers, Extended Symmetrical Optimum method, modal equivalence principle, nature-inspired optimization algorithms, servo systems

SHORT BIO

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Prof. Precup is an IEEE Fellow, in the 2025 class of fellows, "for contributions to fuzzy and data-driven control of servo systems", a corresponding member of The Romanian Academy, a member of the US National Academy of Artificial Intelligence - NAAI, a Fellow of the Asia-Pacific Artificial Intelligence Association, 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.

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