Guest Editorial: Recent Advances in Fuzzy-Based Intelligent IoT and Cyber-Physical Systems

THE rapid development of real-time Internet of Things (IoT) applications including smart grids, smart city, and intelligent transport networks generate a tremendous amount of data from massively distributed sources, which require high computing and communication demand that frequently exceeds the users' requirements. Furthermore, many emerging IoT applications including remote surgery, machine monitoring and control, fault detection, and healthcare generate delay-sensitive tasks, which require timely processing with minimum delay. Besides that, cyber-physical systems (CPS) integrate computing and communication capabilities with monitoring and control of entities in the physical world. These systems are usually composed of a set of networked agents, including sensors, actuators, control processing units, and communication devices. All the critical infrastructures are also a part of the cyber-physical ecosystem to enable smart and connected environments. CPS, including mobile CPS and IoT, embed software into the physical world. They can be used for numerous critical applications in a wide spectrum of fields, such as aerospace, automotive, consumer appliances, energy, entertainment, healthcare, manufacturing, transportation, and so forth, have become a core transdisciplinary area of research, both in industry and academia.

In recent times, fuzzy logic and fuzzy inference system are required to analyze the IoT applications and CPS by monitoring the real-time information and sensed data. Despite the various advantages of the integration of fuzzy logic and fuzzy inference system with the different intelligent frameworks for various IoT applications, the appropriate application of the fuzzy logic and fuzzy inference system poses several challenges including data volume and quality, integration, and accuracy of the inferences drawn from the collected data. Besides that, fuzzy logic and fuzzy inference system are selected to train the local edge/fog devices locally and produce a global model under the coordination of a central edge/fog/cloud server. Therefore, the collaboration of fuzzy systems with intelligent IoT and CPS has proved to present new challenges to modeling and networking due to their intrinsic complexity arising from the tight coupling of computation, communication, and control with physical systems.

The response to our call for this special issue of IEEE TRANSACTIONS ON FUZZY SYSTEMS was overwhelming, as we received in total of 46 submissions from around the world. During the review process, each article was assigned to and reviewed by at least three experts in the field, with a rigorous multiround review process. Thanks to the great support from Editor-in-Chief Jon Garibaldi, and the dedicated work of numerous reviewers, we were able to accept 10 excellent articles covering various topics in fuzzy-based Intelligent IoT and CPS. In the following, we will introduce these articles and highlight their main contributions.

In [A1], Guo et al. designed a smoothing-based fuzzy detection strategy for the IoT applications. The proposed model transforms the previous label spaces into the distributed form using generative adversarial learning.

In [A2], Lv et al. have proposed a nonsingular fixed-time fuzzy fault-tolerant control system with flight state constraints for HFV systems. Furthermore, the authors have introduced a piecewise but different switching control laws to avoid singularity issues, which are often encountered in fixed-time designs.

In [A3], Chen et al. have designed a real-time intelligent translation system while utilizing data-driven fuzzy target representation. The authors have designed two fuzzy methods for the global contextual information: bag-of-word of the target language and target sentence retrieved from the translation memory.

In [A4], Dharejo et al. have presented a fuzzy-based framework for temporal activity recognition in the IoT applications using RNN and 3D-DWT. Furthermore, the authors have developed a novel rank-based fuzzy strategy for segregating activities by ranking the probabilities of activities based on confidence scores.

In [A5], Xu et al. have designed a game theory approach for distributed internet of vehicle task offloading with fuzzy neural network in edge computing. To reduce the task processing latency, the authors have developed a task offloading mechanism using Takagi–Sugeno fuzzy neural network and game theory.

In [A6], Li et al. have proposed a runtime intrusion detection framework for IoT networks utilizing full Bayesian Possibilistic Clustering and Ensembled Fuzzy Classifiers. The proposed framework incorporates a full Bayesian clustering module for feature processing and an ensemble module for dynamically fitting the streaming data.

In [A7], Ahmed et al. have proposed a Fuzzy Active learning technique to detect OpenCL kernel heterogeneous machines in CPS. Besides that, the proposed technique integrates an active learning model based on entropy with a fuzzification model to find the nonoverlapping patterns.

In [A8], Zhao et al. have proposed a multiobjective multiple mobile sink scheduling via evolutionary Interval Type-2 fuzzy

Digital Object Identifier 10.1109/TFUZZ.2022.3202261

rough neural network for wireless sensor networks. The proposed model is constructed a neural evolutionary framework based on the parallel multiobjective evolutionary algorithm.

In [A9], Pan et al. have introduced a side-channel fuzzy analysis-based AI model extraction attack with information-theoretic perspective in intelligent IoT. The proposed AI model integrates power trace-based structure, hierarchical weight extractions, and execution time-based meta parameters. Besides that, the authors have developed the information theory-based analysis for extracting AI models through side-channel attacks.

In [A10], Hussain et al. have proposed cloud risk management with ordered weighted average (OWA)- long short-term memory predictive intelligence and fuzzy linguistic decision making. The OWA operator is weighted with a minimax disparity approach to managing the risk of service level agreement violation in the cloud environment.

ACKNOWLEDGMENT

We would like to express our sincere thanks to all the authors for submitting their articles and to the reviewers for their valuable comments and suggestions that significantly enhanced the quality of these articles. We are also grateful to Prof. Jon Garibaldi, the Editor-In-Chief of IEEE TRANSACTIONS ON FUZZY SYSTEMS, for their great support throughout the whole review and publication process of this special issue, and, of course, all the editorial staff. We hope that this special issue will serve as a useful reference for researchers, scientists, engineers, and academics in the field of Intelligent IoT and CPS.

MAINAK ADHIKARI, *Guest Editor*
Department of Computer Science
Indian Institute of Information Technology
Lucknow
Lucknow 226002, India
mainak@iiitl.ac.in

VARUN G. MENON, *Guest Editor*
Department of Computer Science and Engineering
SCMS School of Engineering and Technology
Kochi 683576, India
varunmenon@scmsgroup.org

JU H. PARK, *Guest Editor*
Department of Electrical Engineering
Yeungnam University
Gyeongsan 712-749, South Korea
jessie@ynu.ac.kr

DANDA B. RAWAT, *Guest Editor*
Department of Electrical Engineering and
Computer Science
Howard University
Washington, DC 20059 USA
db.rawat@ieee.org

APPENDIX: RELATED ARTICLES

[A1] Z. Guo, K. Yu, A. Jolfaei, F. Ding, and N. Zhang, "Fuz-spam: Label smoothing-based fuzzy detection of spammers in IoT," *IEEE Trans. Fuzzy Syst.*, vol. 30, no. 12, Dec. 2022, doi: 10.1109/TFUZZ.2021.3130311.

[A2] M. Lv, Y. Li, L. Wan, J. Dai, and J. Chang, "Fast nonsingular fixed-time fuzzy fault-tolerant control for HFVs with guaranteed time-varying flight state constraints," *IEEE Trans. Fuzzy Syst.*, vol. 30, no. 12, Dec. 2022, doi: 10.1109/TFUZZ.2022.3157393.

[A3] K. Chen, M. Yang, T. Zhao, and M. Zhang, "Data-driven fuzzy target representation for intelligent translation system," *IEEE Trans. Fuzzy Syst.*, vol. 30, no. 12, Dec. 2022, doi: 10.1109/TFUZZ.2022.3167129.

[A4] F. A. Dharejo et al., "Fuzzy Act: A fuzzy-based framework for temporal activity recognition in IoT applications using RNN and 3D-DWT," *IEEE Trans. Fuzzy Syst.*, vol. 30, no. 12, Dec. 2022, doi: 10.1109/TFUZZ.2022.3152106.

[A5] X. Xu et al., "Game theory for distributed IoV task offloading with fuzzy neural network in edge computing," *IEEE Trans. Fuzzy Syst.*, vol. 30, no. 12, Dec. 2022, doi: 10.1109/TFUZZ.2022.315800.

[A6] F.-Q. Li, R.-J. Zhao, S.-L. Wang, L.-B. Chen, A. W.-C. Liew, and W. Ding, "Online intrusion detection for IoT systems with full bayesian possibilistic clustering and ensembled fuzzy classifiers," *IEEE Trans. Fuzzy Syst.*, vol. 30, no. 12, Dec. 2022, doi: 10.1109/TFUZZ.2022.3165390.

[A7] U. Ahmed, J. C.-W. Lin, G. Srivastava, M. S. Mekala, and H.-Y. Jung, "Fuzzy active learning to detect OpenCL kernel heterogeneous machines in cyber physical systems," *IEEE Trans. Fuzzy Syst.*, vol. 30, no. 12, Dec. 2022, doi: 10.1109/TFUZZ.2022.3167158.

[A8] J. Zhao, B. Cao, X. Liu, P. Yang, A. K. Singh, and Z. Lv, "Multiobjective multiple mobile sink scheduling via evolutionary fuzzy rough neural network for wireless sensor networks," *IEEE Trans. Fuzzy Syst.*, vol. 30, no. 12, Dec. 2022, doi: 10.1109/TFUZZ.2022.3163909.

[A9] Q. Pan, J. Wu, A. K. Bashir, J. Li, and J. Wu, "Side-channel fuzzy analysis based AI-Model extraction attack with information theoretic perspective in intelligent IoT," *IEEE Trans. Fuzzy Syst.*, vol. 30, no. 12, Dec. 2022, doi: 10.1109/TFUZZ.2022.3172991.

[A10] W. Hussain, M. R. Raza, M. Ahmed Jan, J. M. Merigo, and H. Gao, "Cloud risk management with OWA-LSTM predictive intelligence and fuzzy linguistic decision making," *IEEE Trans. Fuzzy Syst.*, vol. 30, no. 12, Dec. 2022, doi: 10.1109/TFUZZ.2022.3157951.