Guest Editorial: Fuzzy Systems Toward Human-Explainable Artificial Intelligence and Their Applications

FUZZY SYSTEMS is one of the most significant components in computational intelligence and has performed outstanding modeling capabilities in many data science and decision-making scenarios, based on approximate reasoning under uncertainty consistent with the human thinking process. For example, investigating from fuzzy logic to a learning system can facilitate understanding the accuracy and interpretability of associated artificial intelligence (AI) approaches and further strengthen the trust of current AI systems when interacting with humans to achieve human-explainable AI. In this sense, we believe the design of interpretable fuzzy systems retains the original nature of revealable intelligibility and improves the robustness of AI to lead the evolution of human-explainable AI.

This Special Issue of IEEE TRANSACTIONS ON FUZZY SYSTEMS has succeeded in exploring foundation methodologies, the latest directions, and emerging applications in a new generation of fuzzy systems related to human-explainable AI. The presented studies offer a snapshot of the latest advances in human-centric intelligence and interdisciplinary research, including computational behavioral science, learning methods for interpretable models, theoretical approaches and knowledge representation to explainability, decision support systems, and fuzzy control systems to explain robot behavior. They provided comprehensible explanations of AI decisions that enhanced the training performance on the benchmarks and the transparency through an interface to the end-users and engineers. Ten articles were finally accepted after rigorous reviewing processes and became part of this dominant IEEE TRANSACTIONS ON FUZZY SYSTEMS Special Issue.

In [A1], Mendel and Bonissone discussed TSK fuzzy-rule-based systems that explored linguistic approximation and similarity with examples, and explained why the choice for antecedent membership function shapes that is critical for XAI. This study mainly focused on transparency of describing rule-based fuzzy systems to apply for AI system identification and made some promising future research suggestions and directions.

In [A2], Juang *et al.* proposed a system that can track 3-D hand palms from the whole human standing body using a fuzzy rule-based fusion of explainable visually and linguistically fuzzy features and real-time computational efficiency from a monocular video. The comprehensive tracking experimental results verified the real-time computational ability and accuracy of the proposed system.

In [A3], Dong *et al.* presented a hesitant fuzzy belief structure based on belief functions and hesitant fuzzy sets theories, and included a combination rule to evaluate it in a wearable human activity recognition system. The experimental findings supported the effectiveness and superiority of the application system.

In [A4], Gan *et al.* designed a pattern growth fuzzy utility mining to explore fuzzy high-utility sequences data with linguistic meaning. Through extensive experimental evaluation, the result achieved high efficiency in running time and memory cost, and supported human-explainable mining outputs for decision making.

In [A5], Zhao *et al.* considered the acceleration technique to reduce the scale of computation in rule induction by proposing a rule-based classifier based on fuzzy rough theory, and incorporated an accelerator for rule induction to avoid redundant computation. The extensive experiments demonstrated the high-speed performance by using the accelerator in the proposed classifier, especially on datasets with numerous instances.

In [A6], Guo *et al.* focused their attention on supervised scenarios, which require expert samples with labels for training. They proposed a fuzzy detection system for rumors through explainable adaptive learning from a graph embedding-based generative adversarial network. A set of real-world experiments revealed a superior performance that averagely exceeds benchmarks.

In [A7], Cai *et al.* formulated an effective coal production decision-making scheme to support complex coal production systems for sustainable development. The authors proposed a five-objective fuzzy decision-making model (i.e., economic, energetic, environmental, coal gangue, and safety profits). The results from benchmark simulations showed the proposed model solutions on various metrics, and achieved the best convergence and diversity for the coal fuzzy decision-making problem.

In [A8], Chang *et al.* proposed a multiobjective hybrid approach combining a genetic algorithm and particle swarm optimization, which is used for constructing and training fuzzy logic controllers to coordinate a robotic team performing collision-free navigation and arriving simultaneously at a target location in an unknown environment. The authors also designed a grouping and merging mechanism to obtain transparent fuzzy sets and integrate this mechanism into the training process. Simulation results demonstrated the effectiveness of the proposed approach in reliably solving the proposed navigation problem.

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In [A9], Goli *et al.* designed a fuzzy mixed-integer linear programming model for cell formation problem where several automated guided vehicles are in charge of transferring the exceptional parts. The authors investigated the role of cars and human factors as indispensable components of automation systems in the cell formation and scheduling of elements with a hybrid genetic and optimization algorithm. The experimental results highlighted the proposed algorithm's best computational efficiency and accuracy to resolve this N-P complicated competitive problem.

In [A10], Zhang *et al.* addressed the issue of sarcasm detection in conversation by proposing a complex-valued fuzzy network by leveraging the mathematical formalisms of quantum theory and fuzzy logic. It targets at intrinsic vagueness and uncertainty of human language in emotional expression and understanding. Extensive experiments were conducted on sarcasm detection Reddit track datasets, and the results showed that the proposed network outperformed a wide range of strong baselines.

We guest editors trust that this special issue underlines and further strengthens the particular and unique position of IEEE TRANSACTIONS ON FUZZY SYSTEMS worldwide as a *premium journal* of academic excellence and scientific foresight, rigor, and vision. Now, we wish you all significant enrichment and joy when first browsing through, and then reading in detail this exciting piece of work.

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APPENDIX: RELATED ARTICLES

[A1] J. M. Mendel and P. P. Bonissone, "Critical thinking about explainable AI (XAI) for rule-based fuzzy systems," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 12, Dec. 2021, doi: 10.1109/TFUZZ.2021.3079503.

[A2] C.-F. Juang, C.-W. Chang, and T.-H Hung, "Hand palm tracking in monocular images by fuzzy rule-based fusion of explainable fuzzy features with robot imitation application," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 12, Dec. 2021, doi: 10.1109/TFUZZ.2021.3086228.

[A3] Y. Dong *et al.*, "Evidential reasoning with hesitant fuzzy belief structures for wearable human activity recognition," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 12, Dec. 2021, doi: 10.1109/TFUZZ.2021.3079495.

[A4] W. Gan, Z. Du, W. Ding, C. Zhang, and H.-C. Chao, "Explainable fuzzy utility mining on sequences," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 12, Dec. 2021, doi: 10.1109/TFUZZ.2021.3089284.

[A5] S. Zhao *et al.*, "An accelerator for rule induction in fuzzy rough theory," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 12, Dec. 2021, doi: 10.1109/TFUZZ.2021.3101935.

[A6] Z. Guo, K. Yu, A. Jolfaei, A. K. Bashir, A. O. Almagrabi, and N. Kumar, "A fuzzy detection system for rumors through explainable adaptive learning," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 12, Dec. 2021, doi: 10.1109/TFUZZ.2021.3052109.

[A7] X. Cai, J. Zhang, Z. Ning, Z. Cui, and J. Chen, "A many-objective multistage optimization-based fuzzy decision-making model for coal production prediction," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 12, Dec. 2021, doi: 10.1109/TFUZZ.2021.3089230.

[A8] Y.-C. Chang *et al.*, "Interpretable fuzzy logic control for multi-robot coordination in a cluttered environment," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 12, Dec. 2021, doi: 10.1109/TFUZZ.2021.3111446.

[A9] A. Goli, E. B. Tirkolaee, and N. S. Aydin, "Fuzzy integrated cell formation and production scheduling considering automated guided vehicles and human factors," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 12, Dec. 2021, doi: 10.1109/TFUZZ.2021.3053838.

[A10] Y. Zhang *et al.*, "CFN: A complex-valued fuzzy network for sarcasm detection in conversations," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 12, Dec. 2021, doi: 10.1109/TFUZZ.2021.3072492.