Editorial
CFP: IEEE Transactions on Industrial Informatics—Special Section on Digital Twin for Industrial Internet of Things

RELYING on multiple technologies to connect industrial devices and systems, the Industrial Internet of Things (IIoT) integrates machines, cloud computing, analytics and people to improve the performance and productivity of industrial processes. The success of the IIoT relies on dynamic perception and intelligent decision-making, which is unimaginable due to the heterogeneity of industrial equipment, the complexity of industrial environments, and the sophisticated business operation strategies.

As an emerging digital technology, digital twin provides a feasible solution for capturing complex industrial environments and formulating predictive strategies. It builds virtual representations of industrial entities and manufacturing processes, updated with the physical entities at a specified fidelity and frequency. For example, for industrial manufacturers, digital twin can create digital models of physical machines, help us fully understand how these machines work, make possible modifications or predictive maintenance, and take effective measures before investing large resources and expenditures.

The convergence of digital twins and IIoT is enabling the digital revolution in industrial automation. Researchers from industry and academia have focused on the virtualization and digitization of industrial objects, but there are still many challenges, such as high-fidelity modularity of digital twins, synchronization between digital and physical objects, interaction and networking among digital twins, and scalable and resilient design of digital twin for IIoT.

Following a rigorous review process from a great deal of submissions (71), only a few articles (7) have been accepted for publication in this Special Issue (SI). The acceptance rate is about 9.86%. Each submission received at least three detailed review comments. We introduce the seven accepted papers in the following.

In [A1], Guo et al. propose a novel architecture for improving the performance of 6G IIoT networks using digital-twin technology and D2D communication. It is worth mentioning that this work integrated federated reinforcement learning with digital twins to provide a privacy and overhead awareness optimization solution. The proposal in this article can serve as an excellent paradigm for applying digital twins to network optimization.

In [A2], Fan et al. propose a digital-twin-based adaptive update scheduling framework for satellite network. By establishing a dynamic digital twin of the air–ground network, the dynamic characteristics of the contact window were described, and the satellite network contact window data captured by the digital twin was used as the experimental data to support and verify the superiority of the proposed method.

The combination of digital twin and blockchain technology has great potential to achieve enhanced security, accountability, and integrity. In [A3], Zhang et al. present the architecture of blockchain-based smart parking in digital-twin empowered vehicular sensing networks (VSNs), where the VSN and the corresponding digital-twin networks collaboratively sense and analyze real-time traffic conditions nearby each available parking lot. This work realizes resource management with privacy protection through blockchain and digital-twin technology, which will have a huge impact on the secure integration of digital twins and IIoT. In [A4], Song et al. propose an interesting approach capable of allocating distributed resources in the IIoT to improve the quality of virtual reality-embedded digital twin services, considering the technological capabilities of blockchain technology.

In [A5], Qin et al. consider how digital twin plays a role in a dynamic industrial environment, such as battery discharge. In this article, the authors propose a digital-twin model for lithium-ion battery state of health estimation to accurately estimate maximum available capacity in a real-time way with only partial discharge data. Experiments on multiple battery cells demonstrate that the proposed digital twin provides good end-of-cycle and real-time estimation results. The proposed mechanism is an elegant breakthrough that has been demonstrated by the intelligent battery discharge as a typical use case.

Digital twin enables real-time synchronization and simulation of data from various physical components of industrial control systems, providing insights into issues related to data privacy and cybersecurity. However, anomaly detection of twin data is still challenging because existing methods are usually multistage with tedious training and detection steps. In this vein, in [A6], Li et al. propose an end-to-end anomaly detection method that can be well applied to real-time detection of

Date of current version 4 May 2023.
Digital Object Identifier 10.1109/TII.2023.3261167

sensor and actuator data in digital-twin systems. The results of this study indicate that the proposed model performs well on precision and F1-score in comparison to the state-of-the-art methods.

In [A7], Sui et al. proposed a graph digital twin (GDT) by combining digital-twin technology with graph theory, to describe the logical relationships between physical entities more accurately in digital space, a novel situation awareness model for internet of energy (IoE) based on GDT is proposed. In order to make full use of the relationship between nodes, two classifiers based on graph convolution network are designed for fault location and stability prediction, respectively. The performance evaluations demonstrate the practicability of the proposed framework in scenarios of fault location and stability prediction in the IoE.

In closing, we would like to thank all the authors who significantly contributed to this SI. Meanwhile, we are also grateful to the reviewers for their efforts in providing helpful suggestions to the authors to improve the quality of the articles. We would particularly like to thank Gerhard P. Hancke, the Editor-in-Chief, and the publishing team for their support during this SI.

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APPENDIX: RELATED REFERENCES

[A1] Q. Guo, F. Tang, and N. Kato, "Federated reinforcement learning-based resource allocation for D2D-aided digital twin edge networks in 6G Industrial IoT," *IEEE Trans. Ind. Informat.*, early access, Dec. 8, 2022, doi: 10.1109/TII.2022.3227655.

[A2] H. Fan, J. Long, L. Liu, and Z. Yang, "Dynamic digital twin and online scheduling for contact window resources in satellite network," *IEEE Trans. Ind. Informat*, early access, Dec. 12, 2022, doi: 10.1109/TII.2022.3228682.

[A3] C. Zhang, L. Zhu, and C. Xu, "BSDP: Blockchain-based smart parking for digital-twin empowered vehicular sensing networks with privacy protection," *IEEE Trans. Ind. Informat*, early access, Nov. 18, 2022, doi: 10.1109/TII.2022.3223211.

[A4] J. Song, Y. Kang, Q. Song, L. Guo, and A. Jamalipour, "Distributed resource optimization with blockchain security for immersive digital twin in IIoT," *IEEE Trans. Ind. Informat*, early access, Nov. 28, 2022, doi: 10.1109/TII.2022.3224986.

[A5] Y. Qin, A. Arunan, and C. Yuen, "Digital twin for real-time Li-Ion battery state of health estimation with partially discharged cycling data," *IEEE Trans. Ind. Informat*, early access, Jan. 17, 2023, doi: 10.1109/TII.2022.3230698.

[A6] Z. Li, M. Duan, B. Xiao, and S. Yang, "A novel anomaly detection method for digital twin data using deconvolution operation with attention mechanism," *IEEE Trans. Ind. Informat*, early access, Dec. 26, 2022, doi: 10.1109/TII.2022.3231923.

[A7] L. Sui, X. Guan, C. Cui, H. Jiang, H. Pan and T. Ohtsuki, "Graph learning empowered situation awareness in internet of energy with graph digital twin," *IEEE Trans. Ind. Informat*, early access, Dec. 8, 2022, doi: 10.1109/TII.2022.3227641.

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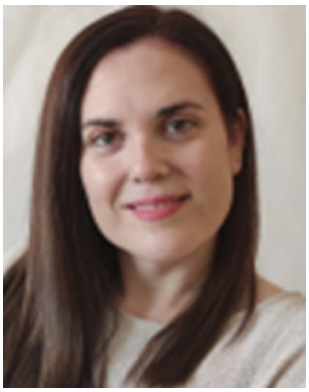

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