Guest Editorial: Human-Cyber-Physical Systems for Intelligent Manufacturing: An Emerging Area

I. Introduction

INTELLIGENT manufacturing (IM) emerges as the full integration of advanced information and manufacturing technologies. It not only affects the way products are manufactured but also creates new opportunities for the design of smart products, processes, services, and systems [1], [2], [3]. IM represents the industrial revolution and provides a framework to address the challenges arising in the integration of cyber systems and physical resources. Cyber-physical system (CPS) [4], [5], [6] is a key enabling technology to realize IM. However, recent research on CPS for IM mainly focuses on the communication, computation, and automation of physical resources (e.g. different machines, robots, and manufacturing units), which overlooks the significant effect of human operators and decision-makers on IM systems. Although some heavy physical labor work and simple repetitive operations have been replaced by machines or robots, humans are the essential elements of true IM systems because their experience and tacit knowledge are non-substitutable for dealing with many high-level and uncertain tasks. Thus, understanding the role of humans in IM is becoming a crucial research area.

Human-cyber-physical System (HCPS) is valued for its potential to illustrate the complex interactions among humans, cyber systems, and physical resources. It highlights human cognition and behavior as a key inclusive part of the system instead of an external factor. HCPS increases the ability of systems to handle uncertain and complicated problems through human–machine interaction. It also enhances the cognition abilities of humans through advanced information technologies and artificial intelligence. From a lifecycle perspective, HCPS can facilitate IM in three dimensions which are intelligent products, intelligent production, and intelligent services.

This Special Issue on Human-Cyber-Physical Systems for Intelligent Manufacturing of IEEE Transactions on Automation Science and Engineering (TASE) is oriented to the dissemination of the state-of-the-art research of methods, techniques, and tools dedicated to HCPS for IM as an important emerging field. Many papers have been submitted to this Special Issue, but due to space limitations, only 21 papers are accepted after a rigorous peer review process. We hope that these selected papers will produce long-lasting impacts on the research community and stimulate more work in this exciting and emerging area.

II. Summaries of Papers in This Special Issue

In [A1], Lou et al. review the state-of-the-art of industrial HCPS from a human-centric perspective. A united architecture is proposed to encompass the aspects of cognitive-to-technology integration and human-to-human interaction in HCPS, highlighting human-in-the-loop, human-on-the-loop, and human-in-the-society paradigms. The mechanisms of these paradigms and their effects on design, production, and service are investigated to expand the research landscape of intelligent manufacturing in Industry 5.0.

In [A2], Lin et al. solve a task scheduling problem with deadline constraints in HCPS by developing an autoencoder-embedded iterated local search algorithm. This approach finds low-order and high-fit sub-solutions via unsupervised end-to-end learning and generates promising solutions in an informative low-dimensional solution space. To further reduce the computational burden, a two-stage optimization framework is constructed, which includes offline training and online optimization phases.

In [A3], Jiang et al. propose a health state assessment approach based on hierarchical data fusion and apply it in a nuclear power plant. A multiple hierarchy consisting of equipment, systems, and functions is established as a physical basis for HCPS. Incremental learning is adopted to improve the performance of random forests, which evaluates the operation function by considering small-scale and imbalanced instances in different health levels.

In [A4], Li et al. develop an upper limb prosthesis with a vision-based manipulation and grasping strategy. The proposed whole-body safety-critical control mechanism includes vision servoing, and multi-task planning with strict priorities, which can be formulated as a hierarchical multi-task optimization problem with safety conditions—expressed as control barrier functions.

In [A5], Wisniewski et al. put forward a modeling and analysis technique of the system supporting the implementation of additive manufacturing specified by an interpreted Petri net. The proposed method allows for the detection of possible unbounded places. Contrary to the most popular analysis methods (which own the exponential complexity in general cases), it is proved that the presented technique is bounded by a cubic polynomial with the number of Petri net nodes. This can be viewed as a breakthrough result in system design and analysis with Petri nets.

In [A6], Zhang et al. construct a knowledge graph for steel surface defects by fusing the multi-source and heterogeneous

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industrial data, including process parameters, chemical compositions, defect images, operation logs, and empirical knowledge. A policy-based reinforcement learning approach is developed to solve the path reasoning problem over the industrial knowledge graph in defect detection and diagnosis.

In [A7], Saeedi et al. develop a non-singular terminal sliding mode controller for tracking and stabilizing tasks in uncertain electro-hydraulic robot manipulators. They employ an event-based strategy to reduce the communication burden on the network layer and achieve resiliency against cyber-attacks. Furthermore, an analytical model of an uncertain 7-DoF manipulator with a hydraulic model of the joints and actuators is employed to capture the nonlinear nature of the robot.

In [A8], Xia et al. propose a navigation and optimization approach for mobile robots operating in IM scenarios with unknown obstacles. They adopt a knee-guided multi-objective evolutionary algorithm and then integrate it with the local navigation framework to enable obstacle avoidance in unstructured environments.

In [A9], Proia et al. focus on optimizing the trajectory of a robotic arm in a collaborative industrial environment, ensuring the maximization of the operator's safety and ergonomics without sacrificing production efficiency requirements. They develop a multi-objective optimization strategy for trajectory planning for safe and ergonomic human–robot collaboration.

In [A10], Tian et al. consider the selective maintenance problem among multiple maintenance teams/operators. They develop a multi-objective optimization model to optimize parallel maintenance sequences by considering maintenance profit, cost, team, and resource limitations. An enhanced multi-objective gravitational search algorithm is then developed for solving this model and determining optimal maintenance plans.

In [A11], Zhou et al. propose an inertial motion capture system for human motion digital twin construction. The designed motion capture device is made up of a hub node and inertial measurement units attached to the human body. The proposed algorithm framework supported by sensor fusion and pose calibration algorithms enables us to acquire orientations of sensors and body segments.

In [A12], Shi et al. analyze human reliability by integrating the minimal-cost consensus method into a success likelihood index. Moreover, a game theory-based combination weighting method is developed to acquire the human error probabilities of operational tasks under a 2-tuple linguistic environment.

In [A13], Zhou et al. develop a framework of real-time local reactive planning that enables a robot to quickly adapt its actions through the limited perception of surroundings by using an eye-in-hand camera. They propose a locally observable transition system and interpretably express the task using linear temporal logic. To improve the grasping performance by using local visual perception, a high-resolution grasp network is constructed and applied. It can achieve state-of-the-art results on multiple datasets for various tasks.

In [A14], Zhao et al. develop an HCPS based on skin-inspired triple tactile (SITT) sensors, a data acquisition board, bimanual robotic hands, and human–robot interaction software for efficient bimanual human–robot collaboration. SITT sensors have skin-inspired multilayer microstructures, which integrate three sensors, namely, an interdigital electrode sensor, a flexible force sensor, and a temperature sensor. They can simultaneously or independently measure a material's dielectric property, tactile force and temperature.

In [A15], Zhu et al. consider the process module (PM) failure of multi-cluster tools that are widely adopted in semiconductor manufacturing. They analyze the task sequences and synchronization conditions for robot activities to avoid deadlock in a shared buffer module. They then propose the novel algorithms to synthesize the proper sequences for robots in case of PM failures given process-dominant multi-cluster tools whose optimal steady-state schedule is known.

In [A16], He et al. focus on the fault prediction for papermaking industry and propose pretreatment processes on data upon papermaking knowledge and analysis of paper breaks. They adopt the random forest to extract interrelated features, and establish a prediction model of paper break based on Gaussian mixture models and Mahalanobis distance.

In [A17], Li et al. propose a risk-aware decision-making framework for task allocation and human–robot interaction to achieve a balance between autonomy level and task efficiency. To quantify the efficiency risk, they utilize conditional value-at-risk by considering the uncertainty of human operators. They finally determine the optimal task allocation for a robot by minimizing the efficiency risk while a necessary collection of tasks is established for the human operator.

In [A18], Tong et al. develop an epipolar Transformer block for reliable cross-view cost aggregation and design an edge detection branch to constrain the consistency of epipolar geometry and edge features. The dynamic depth range sampling mechanism based on probability volume is adopted to improve the accuracy of uncertain areas. The proposed algorithm can effectively reconstruct dense scene representations with limited memory bottle block.

In [A19], Qin et al. study a hybrid disassembly line balancing problem regarding human–robot collaboration. They solve the challenge about workload balancing among different lines, in addition to workstations, to achieve optimal results. A combination of linear programming and integer one is proposed to solve the optimization model that is composed of linear and U-shaped disassembly lines, with the objective of maximal disassembly profit.

In [A20], Zhang et al. propose a quality function deployment-based human-centric decision-making approach for disassembly scheme selection. The theory of the interval 2-tuple q-rung orthopair fuzzy sets is proposed to well describe the ambiguity of the environment and avoid information loss/distortion in the information aggregation stage. Moreover, a hybrid multi-attribute decision-making method is presented to obtain the optimal alternative.

In [A21], Wei et al. propose a comprehensive framework for extracting design knowledge from product life cycle data and utilizing the knowledge to inform the design process. A structured storage method is developed to manage such data with multi-source and heterogeneous characteristics. Furthermore, human–machine collaborative pattern extraction, deep learning-based relation extraction, and other data mining techniques are used to extract knowledge from such data.

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APPENDIX: RELATED ARTICLES

[A1] S. Lou, Z. Hu, Y. Zhang, Y. Feng, M. Zhou, and C. Lv, "Human-cyber-physical system for Industry 5.0: A review from a human-centric perspective," *IEEE Trans. Autom. Sci. Eng.*, early access, Feb. 7, 2024, doi: 10.1109/TASE.2024.3360476.

[A2] C. Lin, Z. Cao, and M. Zhou, "Autoencoder-embedded iterated local search for energy-minimized task schedules of human–cyber–physical systems," *IEEE Trans. Autom. Sci. Eng.*, early access, May 4, 2023, doi: 10.1109/TASE.2023.3267714.

[A3] X. Jiang, Y. Feng, Z. Li, Z. Hong, H. Si, and J. Tan, "Hierarchical data fusion-based health state assessment of nuclear power plant operation under human-cyber-physical system architecture," *IEEE Trans. Autom. Sci. Eng.*, early access, Oct. 11, 2023, doi: 10.1109/TASE.2023.3321049.

[A4] Z. Li, J. Huang, P. Zhang, and P. Shi, "Whole-body safety-critical control design of an upper limb prosthesis for vision-based manipulation and grasping," *IEEE Trans. Autom. Sci. Eng.*, early access, Jul. 4, 2024, doi: 10.1109/TASE.2024.3412823.

[A5] R. Wiśniewski, J. Patalas-Maliszewska, M. Wojnakowski, and M. Topczak, "Modeling and analysis of a Petri net-based system supporting implementation of additive manufacturing technologies," *IEEE Trans. Autom. Sci. Eng.*, early access, Aug. 9, 2023, doi: 10.1109/TASE.2023.3301304.

[A6] Y. Zhang, H. Wang, W. Shen, and G. Peng, "DuAK: Reinforcement learning-based knowledge graph reasoning for steel surface defect detection," *IEEE Trans. Autom. Sci. Eng.*, early access, Sep. 11, 2023, doi: 10.1109/TASE.2023.3307588.

[A7] M. Saeedi, J. Zarei, M. Saif, D. Shanahan, and A. Montazeri, "Resilient event-triggered terminal sliding mode control design for a robot manipulator," *IEEE Trans. Autom. Sci. Eng.*, early access, Aug. 3, 2023, doi: 10.1109/TASE.2023.3297119.

[A8] Y. Xia, Z. Li, G. G. Yen, and H. Xia, "A knee-guided evolutionary algorithm based navigation approach for mobile robots in intelligent manufacturing scenarios," *IEEE Trans. Autom. Sci. Eng.*, early access, May 3, 2024, doi: 10.1109/TASE.2024.3394715.

[A9] S. Proia, G. Cavone, P. Scarabaggio, R. Carli, and M. Dotoli, "Safety compliant, ergonomic and time-optimal trajectory planning for collaborative robotics," *IEEE Trans. Autom. Sci. Eng.*, early access, Nov. 16, 2023, doi: 10.1109/TASE.2023.3331505.

[A10] G. Tian, L. Zhang, A. M. Fathollahi-Fard, Q. Kang, Z. Li, and K. Y. Wong, "Addressing a collaborative maintenance planning using multiple operators by a multi-objective metaheuristic algorithm," *IEEE Trans. Autom. Sci. Eng.*, early access, May 16, 2023, doi: 10.1109/TASE.2023.3269059.

[A11] H. Zhou et al., "Toward human motion digital twin: A motion capture system for human-centric applications," *IEEE Trans. Autom. Sci. Eng.*, early access, Feb. 19, 2024, doi: 10.1109/TASE.2024.3363169.

[A12] H. Shi, J.-H. Wang, H.-C. Liu, and S.-M. Wu, "New SLIM method for human reliability analysis based on consensus analysis and combination weighting," *IEEE Trans. Autom. Sci. Eng.*, early access, Apr. 29, 2024, doi: 10.1109/TASE.2024.3392742.

[A13] Z. Zhou et al., "Local observation based reactive temporal logic planning of human-robot systems," *IEEE Trans. Autom. Sci. Eng.*, early access, Aug. 25, 2023, doi: 10.1109/TASE.2023.3304842.

[A14] S. Zhao, Z. Li, H. Xia, and R. Cui, "Skin-inspired triple tactile sensors integrated on robotic fingers for bimanual manipulation in human-cyber-physical systems," *IEEE Trans. Autom. Sci. Eng.*, early access, Oct. 9, 2023, doi: 10.1109/TASE.2023.3320710.

[A15] Q. Zhu, J. Yuan, G. Wang, and Y. Hou, "Scheduling a single-arm two-cluster tool with a process module failure subject to wafer residency time constraints," *IEEE Trans. Autom. Sci. Eng.*, early access, May 29, 2023, doi: 10.1109/TASE.2023.3275703.

[A16] Z. He, G. Chen, M. Hong, Q. Xiong, X. Zeng, and Y. Man, "Process monitoring and fault prediction of papermaking by learning from imperfect data," *IEEE Trans. Autom. Sci. Eng.*, early access, Jul. 6, 2023, doi: 10.1109/TASE.2023.3290552.

[A17] Y. Li, Y. Wang, H. Li, and H. Liu, "Risk-aware decision making for human–robot collaboration with effective communication," *IEEE Trans. Autom. Sci. Eng.*, early access, Nov. 20, 2023, doi: 10.1109/TASE.2023.3306868.

[A18] W. Tong et al., "Edge-assisted epipolar transformer for industrial scene reconstruction," *IEEE Trans. Autom. Sci. Eng.*, early access, Mar. 7, 2024, doi: 10.1109/TASE.2023.3330704.

[A19] S. Qin, C. Xiang, J. Wang, S. Liu, X. Guo, and L. Qi, "Multiple product hybrid disassembly line balancing problem with Human–Robot collaboration," *IEEE Trans. Autom. Sci. Eng.*, early access, Jul. 1, 2024, doi: 10.1109/TASE.2024.3418898.

[A20] H. Zhang, Z. Huang, G. Tian, W. Wang, and Z. Li, "A hybrid QFD-based human-centric decision making approach of disassembly schemes under interval 2-tuple Q-rung orthopair fuzzy sets," *IEEE Trans. Autom. Sci. Eng.*, early access, Sep. 13, 2023, doi: 10.1109/TASE.2023.3301237.

[A21] W. Wei, C. Jiang, and Y. Huang, "A data-driven human–machine collaborative product design system toward intelligent manufacturing," *IEEE Trans. Autom. Sci. Eng.*, early access, Nov. 23, 2023, doi: 10.1109/TASE.2023.3295571.

REFERENCES

[1] F.-T. Cheng et al., Eds., *Industry 4.1: Intelligent Manufacturing With Zero Defects*. Hoboken, NJ, USA: Wiley, Jan. 2022.

[2] L. Li and M. Zhou, *Sustainable Manufacturing Systems: An Energy Perspective*. Hoboken, NJ, USA: Wiley, 2022.

[3] Q. Fang et al., "Process monitoring, diagnosis and control of additive manufacturing," *IEEE Trans. Autom. Sci. Eng.*, vol. 21, no. 1, pp. 1041–1067, Jan. 2024.

[4] Z. Yu, H. Gao, X. Cong, N. Wu, and H. H. Song, "A survey on cyber–physical systems security," *IEEE Internet Things J.*, vol. 10, no. 24, pp. 21670–21686, Dec. 2023.

[5] K. Zhang, Y. Shi, S. Karnouskos, T. Sauter, H. Fang, and A. W. Colombo, "Advancements in industrial cyber-physical systems: An overview and perspectives," *IEEE Trans. Ind. Informat.*, vol. 19, no. 1, pp. 716–729, Jan. 2023.

[6] W. Duo, M. Zhou, and A. Abusorrah, "A survey of cyber attacks on cyber physical systems: Recent advances and challenges," *IEEE/CAA J. Autom. Sinica*, vol. 9, no. 5, pp. 784–800, May 2022.

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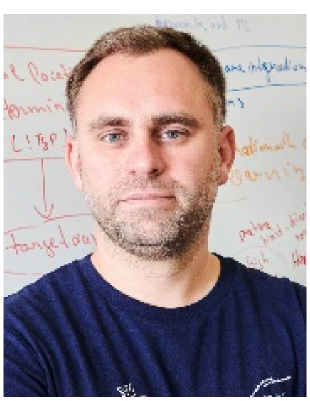

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