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EDITORIAL

Human-Robot collaboration in the next generation manufacturing and logistics system

S. G. Ponnambalam[1] · Qing (Cindy) Chang[2] · Ray Y. Zhong[3] · Ibrahim Kucukkoc[4] · Mukund Nilakantan Janardhanan[5]

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Digitalization, robotics and automation systems have become indispensable components of today's smart production and logistics systems with Industry 4.0. This transformation has revealed a new era of industrialization that greatly increases the interaction between human-machine systems. While such collaboration offers numerous benefits, ensuring smooth and seamless interaction between humans and robots remains a challenge.

This special issue of the Flexible Services and Manufacturing (FSM) Journal aims to identify the role and place of human-robot collaboration (HRC) in the context of rapid development in the field of manufacturing and logistics. The articles published in this special issue will attempt to help identify how digitalized industrial scenarios

✉ S. G. Ponnambalam
ponnambalam.g@vit.ac.in

Qing (Cindy) Chang
qc9nq@virginia.edu

Ray Y. Zhong
zhongzry@hku.hk

Ibrahim Kucukkoc
ikucukkoc@balikesir.edu.tr

Mukund Nilakantan Janardhanan
mukund.janardhanan@leicester.ac.uk

[1] School of Mechanical Engineering, Vellore Institute of Technology, Vellore 632014, India

[2] Department of Mechanical and Aerospace Engineering, University of Virginia, Charlottesville, VA, USA

[3] Department of Industrial and Manufacturing Systems Engineering, The University of Hong Kong, Hong Kong, Hong Kong

[4] Department of Industrial Engineering, Balikesir University, Balikesir, Turkey

[5] School of Engineering, University of Leicester, Leicester LE1 7RH, UK

operate and propose solution techniques to challenges related to human-robot collaboration in complex systems.

There were 13 submissions for this special issue. The following seven papers were accepted for publication after a rigorous peer-reviewing procedure according to the standards of the FSM journal:

- The paper by Wang et al. (2023) addresses the integrated task sequence planning and assignment problem in assembly stations where human workers and robots operate collaboratively. The aim is to enable human workers and robots to perform tasks in a rational and orderly way. A dual-task precedence graph model is developed, and a genetic algorithm-based solution method utilising a two-layer encoding-decoding scheme is applied. The assembly process is simulated to verify the assignment results and prevent any potential collision in this semi-automated assembly station where the time and space are both shared.
- Karuppiah et al. (2023) focus on the identification of challenges in human-robot collaboration and propose an integrated multi-criteria decision-making technique to evaluate them in a real-world industrial community in India. The weight importance of the challenges is calculated by the Fermatean fuzzy system- Analytic Hierarchy Process (FFS-AHP), and the causal interrelationship among the challenges is clarified by the FFS - Decision-Making Trial and Evaluation Laboratory (DEMATEL). Based on the study, it is revealed that the two most important challenges to the establishment of the HRC are task planning and task allocation.
- Tadumadze et al. (2023) deal with the operational planning problem in a multi-level robotic mobile fulfilment system. They present two mixed-integer linear programming models and a matheuristic algorithm to solve the order and pod assignment problem in a multi-level warehouse environment. The aim is to decide which order must be handled at which picking station and from which pods must the ordered items be picked. The problem is solved multi-objectively to (i) balance the total workload among all pickers, (ii) minimise the total order-consolidation effort for the packers, and (iii) minimise the pod movement effort for the mobile robots. It is stated that utilising a multi-level warehouse will increase the consolidation effort of partially picked orders at packing stations.
- Sahin and Tural (2023) introduce the robotic assembly line balancing problem with stochastic task times aiming to minimise the cycle time. It is assumed that human workers and robots operate in different workstations and robots have the capability of performing only certain groups of tasks. The variability of the task times is more for human workers. As the problem includes non-linearity, a mixed-integer second-order cone programming formulation and a constraint programming formulation are developed and solved through commercial solvers. Numerical experiments are conducted through enriching test instances available in the literature and the effects of robots on cycle times are also evaluated.
- Zhang et al. (2023) investigate the flexible assembly workshop scheduling problem, considering the collaborative working environment with human workers and robots. Digital twin models are integrated into reinforcement learning to provide a projection regarding the current status of the assembly process as well as the workforce and equipment. A two-stage reinforcement learning is employed to

achieve an appropriate scheduling strategy through the inspections in a simulated environment when new tasks are introduced, machine malfunctions occur, and disruptive signals are generated. A case study is conducted on ventilation assembly to demonstrate the effectiveness of the proposed method in the rescheduling process of HRC.

- Peng et al. (2023) address the rescheduling problem in the steelmaking-refining-continuous casting (SCC) process, which is considered to be a bottleneck in iron and steel production. A mathematical model is proposed considering dynamic events such as charge start-time delay, which can be encountered in real-world applications. A variable neighbourhood descent method is also proposed and enhanced with newly integrated features to improve the intensification and diversification abilities of the proposed approach. Comprehensive computational tests are conducted for verification against four reference algorithms in the literature, under various CPU time limits.
- Meng et al. (2023) incorporate the preventive maintenance scenarios in balancing and sequencing of mixed-model assembly lines. A mathematical model and a migrating birds optimisation algorithm are proposed to minimise makespan and task alteration. The migrating birds optimisation algorithm is improved to have well-distributed non-dominated solutions. A restart mechanism and an intra-population crossover operator are integrated to increase the search capability of the algorithm. In addition to the experimental study conducted for performance tests of the proposed approach, a case study is also carried out to show the relevance and practicality of the addressed problem.

Acknowledgements We thank all the authors, reviewers, and editorial team of the journal who contribute to making this great collection of articles. We hope that the studies published here will shed light on new academic studies and industrial applications in terms of the development and more effective use of new technologies.

References

Karuppiah K, Sankaranarayanan B, Ali SM, Bhalaji RKA (2023) Decision modeling of the challenges to human-robot collaboration in industrial environment: a real world example of an emerging economy. Flexible Services and Manufacturing Journal

Meng K, Tang Q, Zhang Z (2023) Balancing and sequencing of mixed-model assembly line considering preventive maintenance scenarios: mathematical model and a migrating birds optimization algorithm. Flexible Services and Manufacturing Journal

Peng K, Deng X, Zhang C, Shen W, Song Y, Mou J, Liu A (2023) Elite solutions and Tabu assisted variable neighbourhood descent for rescheduling problems in the steelmaking-refining-continuous casting process. Flexible Services and Manufacturing Journal

Sahin MC, Tural MK (2023) Robotic stochastic assembly line balancing. Flexible Services and Manufacturing Journal

Tadumadze G, Wenzel J, Emde S, Weidinger F, Elbert R (2023) Assigning orders and pods to picking stations in a multi-level robotic mobile fulfillment system. Flexible Services and Manufacturing Journal

Wang Y, Wang J, Feng J, Liu J, Liu X (2023) Integrated Task sequence planning and assignment for Human-Robot Collaborative Assembly Station. Flexible Services and Manufacturing Journal

Zhang R, Lv J, Bao J, Zheng Y (2023) A digital twin-driven flexible scheduling method in human-machine collaborative workshop based on hierarchical reinforcement learning. Flexible Services and Manufacturing Journal

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