# A review of manufacturing systems for introducing collaborative robots


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## ABSTRACT

Industry 4.0 highlights a new industrial revolution for the manufacturing system. This work aims to provide a review of different types of manufacturing systems and present motivations of introducing collaborative robots into manufacturing. We start with a discussion about the existing research of human-robot collaboration as well as its perception and control strategies. Then, we give a review of the current applications of swarm robots in manufacturing. Finally, we propose some insights for future directions of human-robot society.


## INTRODUCTION OF MANUFACTURING SYSTEM

The manufacturing system, which is defined as a collection of labor resources and integrated equipment, is utilized to process and assemble the raw production materials [1]. In this section, five types of manufacturing systems are discussed and compared. We also present the features and potential robot usage of them as shown in Table I.

TABLE I.MANUFACTURING SYSTEM

| Manufacturing system | Features | Potential cobot usage |
|---|---|---|
| Cellular manufacturing | High product variation and highly skilled labor | Task-based HRC to improve efficiency.[2] |
| Flexible manufacturing | High product variation and highly skilled labor | Intelligent assist system for the variate product.[3] |
| Flow Shop | Low product variation and low skilled labor | Solving scheduling problem and manual labor shortage.[4] |
| Reconfigurable manufacturing | Customized flexibility and adaptability | Reconfigurable machine tools. |
| Project shop | Large products and low variation | Air-Cobot for vision inspection.[5] |

## INDUSTRIAL TASKS FOR HUMAN-ROBOT COLLABORATION

The main advantage of human-robot collaboration in the manufacturing system is that robots can assist human operators with sophisticated tasks. In this manner, machines do not replace humans, but they supplement their ability by getting rid of heavy work for workers. Unlike the traditional industrial robots, collaborative robots (cobots) in the manufacturing system can offer more safety and dexterity

TABLE II. SOME STATE-OF-THE-ART IN USING COBOT FOR INDUSTRIAL TASK

| Industrial scenarios | Tasks | Advantages |
|---|---|---|
| BMW [6] | Equipping insulation insider door | Replace human worker |
| Audi [7] | UR3 cobot for adhesive on car roof | Save space |
| Volkswagen [8] | KuKA cobot for screwing on drive train | Easier to reach locations |
| ARM [9] | Prepreg for composite layup | Reduce human operator's workload |

## SWARM ROBOTS IN MANUFACTURING SYSTEM

Why should the swarm robots be incorporated into manufacturing system? Beyond the human robot collaboration, a fully automatic process of manufacturing by a team of robots is more challenging, and the robot-robot collaboration is addressed. Moreover, the setup of the layout and the controller for these inflexible machines often cost much time and money when the design of the product changes.

Mobile robots like unmanned ground vehicle (UGV) and unmanned aerial vehicle (UAV) with good maneuverability can be appropriately utilized to make a difference. Therefore, to enhance the efficiency and robustness of the system, the concept of swarm robotics which is inspired by the collective behaviors of social insects can be introduced

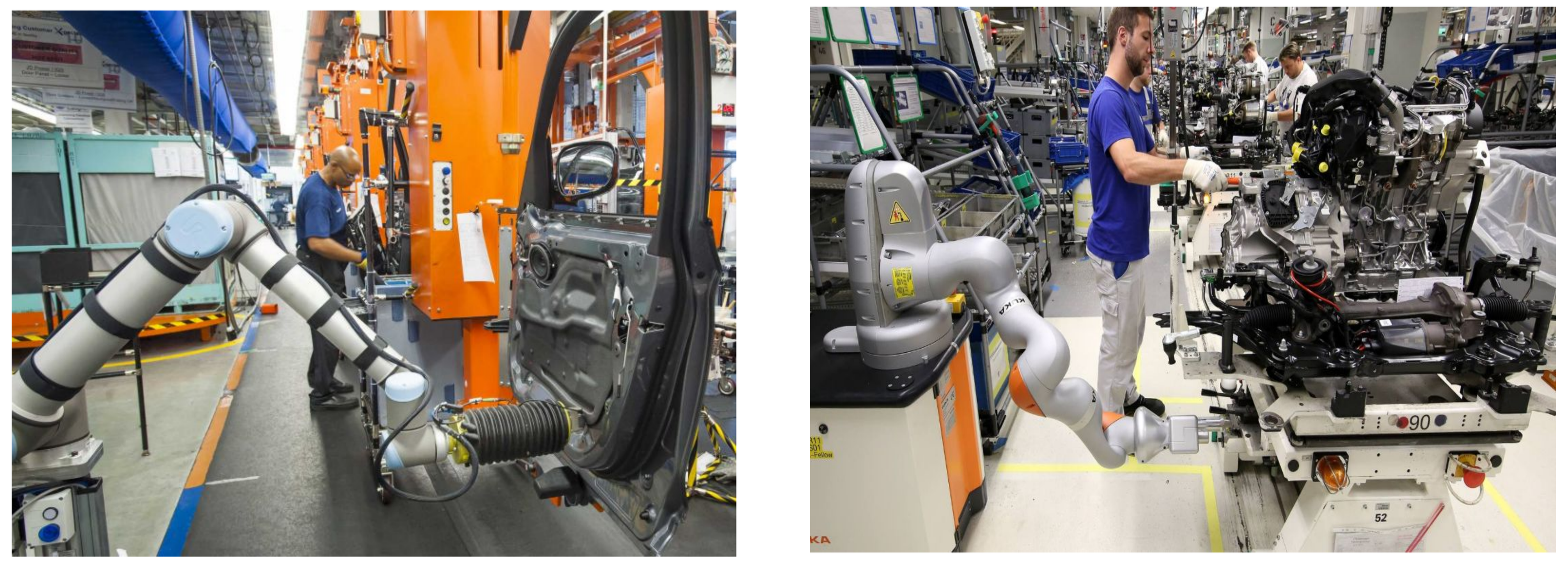

Figure 1. Robot helping with door assembly tasks [7] and with assembly of pendulum supports [9].

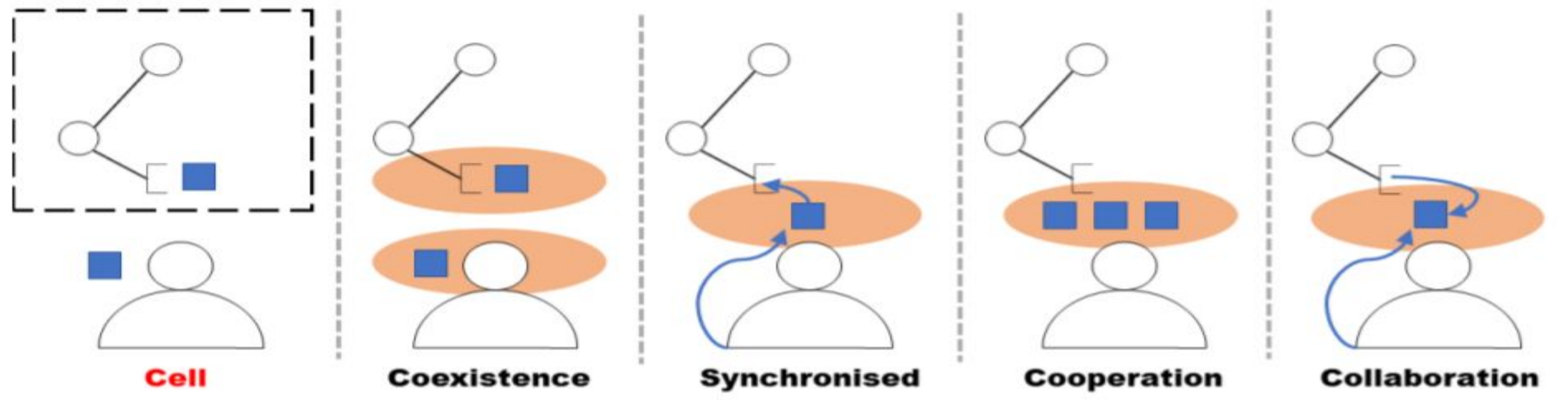


Figure 2. Types of use of a collaborative robot.[6]

## CONCLUSION

This paper investigates and analyzes the current and potential applications of collaborative robots in manufacturing systems. To construct an ecology of the manufacturing system, it might be necessary to pay more attention to human-robot and robot-robot interactions. Thus, the robots should have lifelong learning ability so that they can be easily reconfigured to collaborate better with the human, which makes the manufacturing system move closer towards the standard of Industry 4.0.

## Reference


[1] T. Vamos, "Automation production systems and computer integrated manufacturing. Mikell P. Groover,"Automat-ica, vol. 24, no. 4, p. 587, 1988.

[2]. J. T. C. Tan, F. Duan, Y. Zhang, K. Watanabe, R. Kato,and T. Arai, "Human-robot collaboration in cellular man-ufacturing: Design and development,"2009 IEEE/RSJInternational Conference on Intelligent Robots and Sys-tems, IROS 2009, pp. 29–34, 2009

[3] J. Kr¨uger, R. Bernhardt, and D. Surdilovic, "Intelligent assist systems for flexible assembly,"CIRP Annals -Manufacturing Technology, vol. 55, no. 1, pp. 29–32,2006.

[4] A. R. Sadik and B. Urban, "Flow shop scheduling prob-lem and solution in cooperative robotics—case-study:One cobot in cooperation with one worker,"FutureInternet, vol. 9, no. 3, 2017.

[5] M.-a. Bauda, A. Grenwelge, S. Larnier, M.-a. Bauda,A. Grenwelge, S. Larnier, M.-a. Bauda, A. Grenwelge,and S. Larnier, "3D scanner positioning for aircraftsurface inspection To cite this version : 3D scannerpositioning for aircraft surface inspection," 2019

[6]. N. Giles and M. Hatzel, "Innovative human-robot cooperation in BMW Group Production," 2013. [Online].Available: https://www.press.bmwgroup.com/global/article/detail%20/T0209722EN/innovative-human-robot-cooperation-in-bmw-group-production?language=en

[7]. Audi,"New human-robot cooperation in Audi production processes,"2015. [Online]. https://www.audiusa.com/newsroom/news/press-releases/2015/02/new-human-robot-cooperation-in-audis-production-processes

[8].KUKA,"Many wrenches make light work: KUKA flexFELLOW will provide assistance duringdrive train pre-assembly," 2016. [Online]. https://www.kuka.com/en-de/press/news/2016/10/vw-commits-to-human-robot-collaboration-in-wolfsburg

[9]. Advanced Robotics for manufacturing, "ROBOTICASSISTANTS FOR COMPOSITE LAYUP," 2020. [On-line]. Available: http://arminstitute.org/projects/robotic-assistants-for-composite-layup/

[10] Xiao, Y., Hoffman, J., Xia, T., & Amato, C. (2019). Multi-Robot Deep Reinforcement Learning with Macro-Actions. Retrieved from http://arxiv.org/abs/1909.08776

[11] R. Ritz and R. D'Andrea, "Carrying a flexible payload with multiple flying vehicles," IEEE International Conference on Intelligent Robots and Systems, pp. 3465– 3471, 2013.

[12] Graham, R., Das, J., & Lucas, D. (2016). Towards Coordinated Precision Assembly with Robot Teams. 109, 819–839. https://doi.org/10.1007/978-3-319-23778-7

[13] Werfel, J., Petersen, K., & Nagpal, R. (2011). Distributed multi-robot algorithms for the TERMES 3D collective construction system. Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2011), 1–6.