A Reinforcement Learning based Collaboration Framework for Autonomous Mobile Robots

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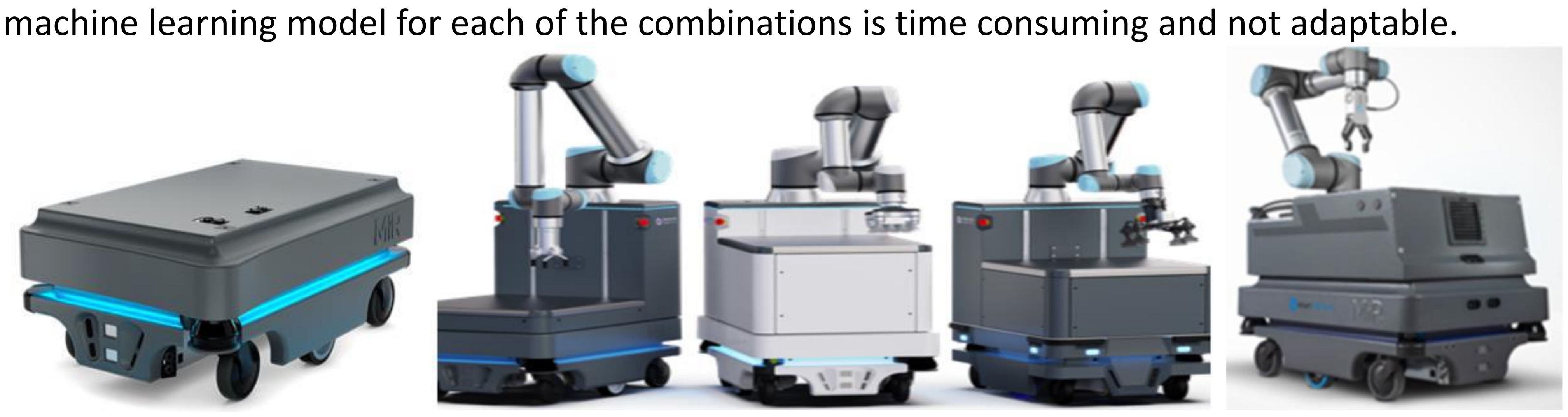
Introduction

Manufacturing has shifted from mass production to mass customisation. The increased product varieties have created significant challenges in the manufacturing process. This demands reconfigurable work cells and manufacturing lines, faster integration time, reusable robotic systems, reduced factory footprint, high-mix and low-volume productions and reduced programming costs. Therefore, an AI based flexible and adaptive robotic control and multi-robot collaboration system is essential to address these challenges and to autonomously react to the environmental and production line changes without human intervention.

Autonomous Mobile Robots (AMR), Fig. 1(a), are proposed to address these agile manufacturing challenges. AMRs are devices that can perform tasks and moving through the environment without the need of a predefined path or intervention from human operators. Integration of AMRs with manipulators (robotic arms) and grippers, Fig. 1(b), can support intelligent gripping and placing tasks, e.g., pick up objects, place them on the AMR platform and move the objects to another place, or pick up the objects and places them to different pallets. In realistic industry environments, there are a large number of possible combinations of these AMRs, the robotics arms, grippers and tasks, e.g., a combination of an AMR/ Robotic Arm/ Gripper can be used for different pick and place tasks, and different combinations of AMR/ Robotic Arm/ Gripper can be used for the same pick and place tasks. Training a machine learning model for each of the combinations is time consuming and not adaptable.



(a) (b)

Fig. 1. (a) Autonomous Mobile Robot, (b) Different Combinations of AMR, Robotic Arm Top Modules & Grippers

Related Work

Karel Čapek, a Czech writer, used the term "robot" for the first time in his play Rossum's Universal Robots (R.U.R) that was written by him in 1920, to signify an artificial human prepared out of artificial organic substance (Joseph, 2015). With regard to modern definition of a robot, according to Britannica (n.d.): *"Any automatically operated machine that replaces human effort, though it might not resemble human beings in appearance or preform functions in a humanlike manner."* This definition may be taken as an elaborate one, but still needs modifications to satisfy the context. The exact date of birth of the first robot is difficult to be determined, however, "The Pigeon", a mechanical bird can be regarded very close to the first robot. "Shakey", a robot built in 1966 by Stanford Research Institute is one such example which is capable of reasoning of its own actions and analyse complicated commands by splitting into smaller statements (Fikes & Nilsson, 1971). Since the time, the robot Shakey independently moved utilising STRIPS (Stanford Research Institute Problem Solver) at Stanford, autonomous mobile robots (AMRs) have been very dynamic and active domain of research. AMRs are mobile and equipped with sensors to enable them to react and adapt to environmental changes (Unger et al., 2018). Various valuable outcomes may be produced in small to medium enterprises (SMEs) by usage of these AMRs including; economic efficiency, process flexibility, scalable automation process stability. In the context of industrial usage and deployment scenarios, collaborative AMR robotics is presently attracting a lot of research interests (Zanchettin et al., 2016). A robot is enabled by reinforcement learning to autonomously determine a best-fit behaviour through trial and error interactive sessions with its surroundings (Kober et al., 2013). The future advancements in designing reinforcement learning-based algorithms and frameworks for robotics in general and AMRs in particular are likely to reap more rewards of the domain of machine learning. At present, there exists lack of worthwhile evidence showing the application of reinforcement learning frameworks for designing of algorithms for AMR-based singular or collaborative manipulator systems to support diverse pick and place tasks.

Research Questions

Q.1: How can reinforcement learning frameworks be effectively applied to design and develop a centralised knowledge module and composition algorithm for AMR-based manipulator system/ pick and place tasks?

Q.2: How can reinforcement learning frameworks be extended to design and develop decentralised/ collaborative knowledge modules and composition system for AMR-based adaptive manipulator system to support diverse pick and place tasks?

Research Contribution

To develop a reinforcement learning based framework and correspondent algorithms to achieve centralised and decentralised knowledge (machine learning model) modularization so that these knowledge modules representing different AMRs/Robotic Arms/Grippers/Tasks are composable.

Proposed Methodology

- Testbed setup and background knowledge acquisition.
- Benchmarking of existing knowledge modularization and composition approaches in a simulated environment.
- Design and develop a centralised knowledge modularization and composition algorithm for AMR-based pick and place tasks.
- Design and develop a decentralised (cooperative) knowledge modularization and composition system for AMR-based pick and place tasks.

Experimental Setup

Towards experimental testbed setup, research specific trainings on Robotic Operating Systems 2, Autonomous Mobile Robotics, Reinforcement Learning using Python environment and related libraries, and acquisition of background knowledge are in progress.

References

Britannica. (n.d.). *Robot: Definition, history, uses, types, & facts.* Retrieved December 27, 2021 from https://www.britannica.com/technology/robot-technology

Fikes, R. E., & Nilsson, N. J. (1971). Strips: A new approach to the application of theorem proving to problem solving. *Artificial Intelligence*, *2*(3–4), 189–208. https://doi.org/10.1016/0004-3702(71)90010-5

Joseph, L. (2015). *Learning robotics using python: Design, simulate, program, and prototype an interactive autonomous mobile robot from scratch with the help of Python, ROS, and Open-CV.* Packt Publishing Ltd.

Kober, J., Bagnell, J. A., & Peters, J. (2013). Reinforcement learning in robotics: A survey. *The International Journal of Robotics Research*, *32*(11), 1238–1274. https://doi.org/10.1177/0278364913495721

Unger, H., Markert, T., & Müller, E. (2018). Evaluation of use cases of autonomous mobile robots in factory environments. *Procedia Manufacturing*, *17*, 254–261. https://doi.org/10.1016/j.promfg.2018.10.044

Zanchettin, A. M., Ceriani, N. M., Rocco, P., Ding, H., & Matthias, B. (2016). Safety in human-robot collaborative manufacturing environments: Metrics and control. *IEEE Transactions on Automation Science and Engineering*, *13*(2), 882–893. https://doi.org/10.1109/TASE.2015.2412256

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