Flexible Scheduling for Human Robot Collaboration in Intralogistics Teams

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Abstract

The project Flexible Intralogistics for Future Factories (FlexIFF) investigates human-robot collaboration in intralogistics teams in the manufacturing industry, which form a cyber-physical system consisting of human workers, mobile manipulators, manufacturing machinery, and manufacturing information systems. The workers use Virtual Reality (VR) and Augmented Reality (AR) devices to interact with the robots and machinery. The right information at the right time is key for making this collaboration successful. Hence, task scheduling for mobile manipulators and human workers must be closely linked with the enterprise's information systems, offering all actors on the shop floor a common view of the current manufacturing status. FlexIFF will provide useful, well-tested, and sophisticated solutions for cyber-physicals systems in intralogistics, with humans and robots making the most of their strengths, working collaboratively and helping each other.

1 Introduction

The manufacturing sector is a highly competitive environment, with many companies seeking to leverage technological advances as a way of getting ahead of their competitors. Moreover, the customers request more and more complex products, a larger number of variants, and small production lots. Additionally, short manufacturing times and high flexibility are required for quick adaptation to the market demands (Silveira et al., 2001). Since shop floor organisation

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based on manufacturing lines has proven to be too inflexible to address these issues, manufacturers have begun to split the manufacturing lines into smaller units, often referred to as islands or cells (Esmaeilian et al., 2016). However, under this arrangement single or lots of products have to be transported between the manufacturing cells, creating new challenges in the transport logistics in a manufacturing plan. The internal transport logistics of a plant is termed 'intralogistics' (Lutz et al., 2016; Berndt et al., 2016).

The project Flexible Intralogistics for Future Factories (FlexIFF) conducts research in the field of human-robot collaboration in intralogistics teams for the manufacturing industry. The project's objective is to combine the strengths of human workers and robots, creating a new cyber-physical system (CPS). Robots should focus on monotonous and physically demanding tasks, while humans should concentrate on supervision and conflict resolution. To that end, mobile robotics platforms with a robotic manipulator arm mounted on the top (commonly referred to as a mobile manipulator) have to be integrated into the enterprise information systems (EIS) in order to obtain up-to-date information about the tasks they have to execute. Furthermore, human workers need Human Computer Interaction (HCI) technologies to interact with the mobile manipulators, receive status information, help with conflict resolution and teach the mobile manipulators new manoeuvres. Additional HCI is required for workers to report problems to the enterprise information systems (EIS) improving the manufacturing scheduling.

The next Section contains a brief introduction to the related work, followed by insights into the integration of mobile manipulators with EIS and HCI technologies, enabling an interaction with mobile manipulators. The concluding Section discusses the current state of the project and provides an outlook on future work.

2 Related Work

Intralogistics is an important aspect of the efficiency of a manufacturing plant. Mobile manipulators can load complex structures on top of themselves or even assist with manufacturing tasks carried out by humans or other robots (Vogel-Heuser et al., 2017). The EIS needs to consider the collaboration of mobile manipulators with other actors on the shop floor when scheduling and controlling the overall manufacturing process. The research project STAMINA has successfully integrated mobile manipulators into the EIS in the automotive industry (Rovida et al., 2016).

Safe collaboration and interaction between human and robots is another important aspect, which was investigated within the project VALERI and its successor, ColRobot (Saenz et al., 2017). To provide the right information at the right time, eye-tracking can be used to develop user attention models (Silva et al., 2018). Such approaches as Virtual Reality (VR) and Augmented Reality (AR) can help humans to interact with information systems, robots, and other humans (Dini et al., 2017). VR has been used in product design, maintenance, product assembly, and remote robot control, while AR has been applied in planning, assembly guidance, design, maintenance, simulation, and robot trajectory planning (Michalos et al., 2016; Andaluz et al., 2016).

3 Methods, Technologies, and Challenges in FlexIFF

The FlexIFF project offers a unique holistic approach to exploring multiple aspects of a manufacturing CPS, conducting research on secure system design, cyber-attack protection, interaction planning, movement planning, conflict resolution, robotic gripper design, machine learning, scheduling, optimisation, decision support, HCI, VR, AR and mixed reality (MR).

Within FlexIFF, multiple prediction models will be evaluated to establish which ones can predict the real progress of manufacturing cells best. The prediction models have to interact with the existing EIS to obtain and unify data from multiple sources in various data formats and granularity. The progress prediction will be used for scheduling the mobile manipulator journeys in advance. The forecasted utilisation of the manufacturing cells is important in terms of prioritising the tasks carried out by the mobile manipulators.

FlexIFF foresees that mobile manipulators share the shop floor with human workers, who supervise the manufacturing using AR devices. Since the AR devices recognise the markers, the workers only have to look at the machinery to obtain the desired information. The workers can also interact with the machinery via the AR devices, e.g., by acknowledging warning messages, reporting errors, or malfunctioning equipment. However, the AR and VR devices do not suffice. A significant research challenge is the automatic selection of relevant information for each worker, since it is unnecessary and distracting (and possibly dangerous) to show all the information at once. FlexIFF will develop and test methods for presenting automatically-selected important information to human workers.

4 Conclusion and Outlook

The FlexIFF project aims to create intralogistics teams consisting of mobile manipulators, humans, and EIS, forming a new CPS. FlexIFF investigates many aspects of CPS, including safety and security, safe gripping, machine learning, scheduling, optimisation, HCI, AR, VR, and MR. Currently, the FlexIFF project is in its development phase. The solutions will be tested in a laboratory environment using a human-machine conflict simulator, which will generate conflict situations to test potential conflicts and provide information overload resolutions. Methodologies proven to be useful and robust will be tested in an experimental manufacturing environment at an electronics manufacturing company.

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