Available online at www.sciencedirect.com

ScienceDirect

IFAC Papers Online
CONFERENCE PAPER ARCHIVE

IFAC-PapersOnLine 49-30 (2016) 018–023

Cooperative Remote Repair Task in an Active Production Line For Industrial Internet Telemaintenance ⋆

Doris Aschenbrenner ** **Felix Sittner** * **Michael Fritscher** * **Markus Krauß** * **Klaus Schilling** **

* *Zentrum für Telematik e.V. (ZfT) 97070 Würzburg (Germany) (Tel: +49 (0)931 615633-63; e-mail: name.surname@telematik-zentrum.de).*
** *University of Würzburg Computer science Chair Robotics and Telematics 97070 Würzburg (e-mail: schi@informatik.uni-wuerzburg.de)*

Abstract: This paper broaches the issue of situation awareness in an industrial robot telemaintenance setting. It covers the specific use case of a motor exchange of the third axis of a Cartesian robot which was supervised remotely. This is a repair task which has never been done remotely in the application domain, particularly not in an active production line. Both people involved – the local technician and the external expert – need to work together via the Internet and both of them perform supervisory control of the manipulator. Their specific needs for functionality and visual feedback can be observed in this example and the results can be useful for other Industrial Internet applications.

Keywords: telemaintenance; industrial robot; Industrial Internet; teleoperation; situation awareness.

1. INTRODUCTION

Germany's 'Industry 4.0' process and similar attempts in the US framed in the wording 'Industrial Internet', mentioned e.g. in Bruner (2013), can be seen as the attempt to apply newer developments of information and communication technology in the industrial automation setting in order to increase productivity and flexibility. This comprises, on the one hand, technologies like cyber-physical systems or the Internet, but, on the other hand, also techniques like human computer interaction. One example for an Industrial Internet application is telemaintenance, which, according to Chowdhury and Akram (2011), refers to the integration of computer science and communication technologies into the maintenance strategy. It is particularly interesting for high-grade capital-intensive goods like industrial robots. Robotics manufacturers sell their technology to customers worldwide. Some of those factories lack qualified personnel for maintenance and repair tasks. When a severe failure occurs, an expert of the manufacturer needs to visit the site, which leads to long down times of the machine or even the whole production line. With the development of data networks, a huge part of those travels can be omitted, if appropriate telemaintenance equipment is provided.

An Industrial Internet setting is depicted schematically in Fig. 1. It includes several machines, but also several humans communicating with each other via a network. The different communication paths are named according to communication source and recipient. As the term 'machine' is used as subordinate concept and an industrial robot is a common machine in many plants, the icon and term is used in an equivalent matter.

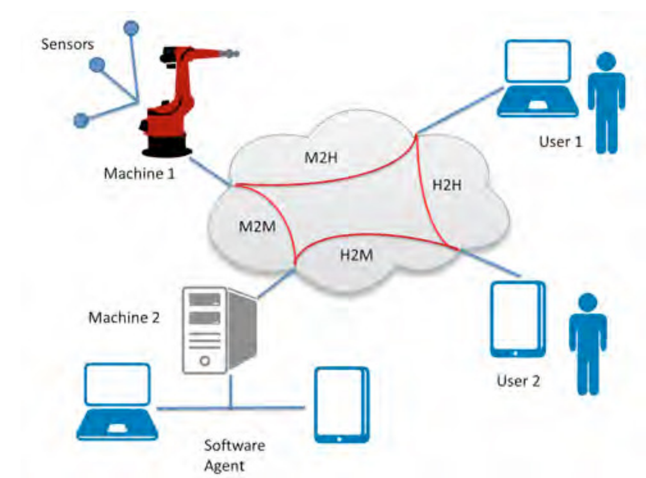

Fig. 1. Communication in an Industrial Internet setting

Spath et al. (2013) line out, that humans will not disappear in modern production lines, but will most certainly work more closely to robots, since the strict separation of working spaces of humans and robots has experienced a softening due to recent robotics research. Taking this into account, the problem "to understand and shape the interactions between one or more humans and one or more robots" as Goodrich and Schultz (2007) frame 'human-robot interaction', will play an important role in industrial

⋆ funded by the Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology in its R&D program 'Information and Communication Technology'.

10.1016/j.ifacol.2016.11.116

Internet applications. This paper shows the results of an experiment on telemaintenance and remote supervised repair on an industrial robot as a specific case of Fig. 1. One user is a local technician who is next to the plant and thus performs proximate interaction with the industrial robot. The other one is a remote expert who is connected via the common Internet. Teleoperation infrastructure enables remote interaction with both the robot and the service technician. Guided by the specific application of a motor exchange this paper aims at answering the question which functionalities and information sources both humans need in order to succeed in their repair tasks.

2. FUNDAMENTALS

2.1 Telemaintenance

Telemaintenance can be seen as a combination of teleoperation and remote condition monitoring. It also involves the cooperation of a virtual team which does not know each other in advance i.e. the service technician and the expert.

In theory, teleoperation of industrial robots has long since been in focus of international research, for example Moradi Dalvand and Nahavandi (2014). In most cases, visual feedback is used to provide information on the state of an industrial robot to a human operator in the control loop.

In practice, 'telemaintenance' is provided mainly via phone communication without any visual feedback or remote access. Furthermore, the expert is specialized on the industrial manipulator, but is not familiar with the specific plant context, as robots are used in a variety of settings. That is why some tasks can simply not be supervised remotely, if the service technician has not been specifically trained on the task in advance. In such cases, the expert service personnel travels to the facility and performs the required repair tasks there.

2.2 Extended Human Supervisory Control

In general, "a robotic teleoperation system allows to reproduce the actions of a human operator and to interact physically with objects and environments placed at a distance" Melchiorri (2014). Hence, it can be seen as a subgroup of human supervisory control introduced by Sheridan (1995).

In the case of telemaintenance, both the local technician and the remote expert perform supervisory control, according to Aschenbrenner et al. (2015b). Due to safety issues in Europe and other parts of the world the legal permission to teleoperate an industrial robot in an automation facility cannot be granted without a local supervisor. The latter needs to maintain control of the industrial robot and his or her control inputs need to have priority over remote commands. In this extended human supervisory control setting the communication between both partners in the virtual team plays an important role for the task achievement.

2.3 Situation Awareness in Teleoperation

The important factor of "understanding what is going on" for the remote expert is called Situation Awareness (SA),

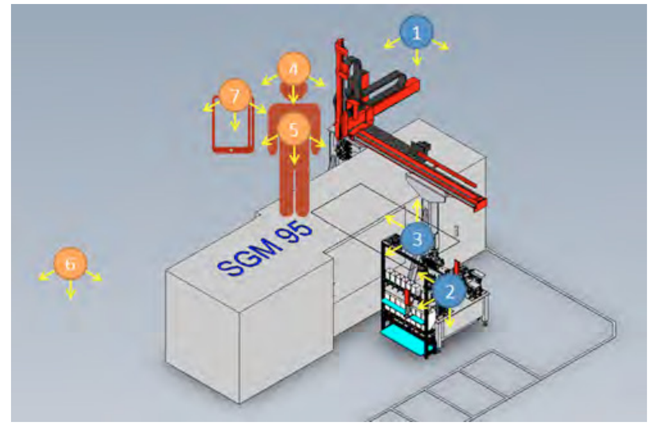

Fig. 2. Experimental setting and camera locations

explained by Endsley (1995). It is used to describe the level of awareness that operators have of the situation in order to perform tasks successfully. Various methods of measuring SA have been proposed, cf. Stanton et al. (2013). Being a critical criterion in safety critical domains, focus of SA exploration laid at first on military and aviation tasks, but the concept was soon also applied to maintenance tasks, as described in Endsley and Robertson (2000).

For measuring SA, freeze probe techniques are well known. As described in Salmon et al. (2009) in "complex real world activities where SA cannot meaningfully be defined beforehand and where the outcomes are not easily predictable", alternative approaches like Critical Decisions Method (CDM), explained in Stanton et al. (2004), and the Situation Awareness Rating Technique (SART), introduced by Taylor (1990), are recommended.

3. EXPERIMENTAL SETUP

3.1 Scenario: Motor Exchange

In 'MainTelRob', a three year research project described by Sittner et al. (2013), different functionalities in the field of 'Industrial Internet' have been developed. In order to evaluate the telemaintenance functionality in a real-world example, a 'proof of concept' study has been performed. Based on the qualitative findings of the contextual analysis for telemaintenance described in Aschenbrenner et al. (2015a), the task of a motor exchange has been chosen: "A motor exchange has never been done remotely. If the local worker does not know what to do, a service technician has to travel abroad." as one manager of a well-known robot manufacturer puts it. A motor exchange for a robot axis is very elaborate. The worker has to prepare several steps (like retaining the axis) and needs at least an hour for the repair, if he is well trained. A service technician who is familiar with the test plant has mentioned: "If someone has never done that, it can take more than three hours."

3.2 Experimental Setting

Evaluation took place at a plant in an active production line which consists of an industrial robot, an injection molding machine and a montage system which is displayed in Fig. 2. There are two stationary cameras which have