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Teleoperation of an Industrial Robot in an Active Production Line

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Abstract: The aim of our research is to develop an industrial internet telecontrol architecture for robots in an active production line. The main objective is to realize teleoperation and telemaintenance tasks, which on the one hand meet user needs of the industry partners and can on the other hand be performed over the common Internet. The involved research fields are human supervisory control, networked control systems and bandwidth management. This report describes the results of some preliminary studies carried out in different testbeds and the real plant. Furthermore, it outlines the resulting teleoperation architecture which is an application of current robotics and control research.

Keywords: Industrial robots, teleoperation, human-machine interface, telecontrol, telematics, telerobotics, maintenance.

1. INTRODUCTION

While teleoperation of technical highly sophisticated systems has already been a wide field of research, especially for space and robotics applications (Lichiardopol (2007)), the automation industry has not yet benefitted from its results. Besides the established fields of application, also production lanes with industrial robots and the surrounding plant are in need of being remotely accessible. This is especially critical for maintenance or if an unexpected problem can't be solved by the local specialists.

Special machine manufacturers, especially robotics companies, sell their technology worldwide. Some factories, for example in emerging economies, lack qualified personnel for repair and maintenance tasks. When a severe failure occurs, an expert of the manufacturer needs to fly there, 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 teleoperation equipment is provided.

This article describes the development of a telemaintenance system, which was established in an active production lane for research purposes. The costumer production site of Braun, which belongs to Procter & Gamble, consists of a six-axis cartesian industrial robot by Kuka Industries, a two-component injection molding system and an assembly unit. The plant produces plastic parts for electric toothbrushes.

In the research project 'MainTelRob', during which this plant was utilised, the Zentrum für Telematik e.V. (ZfT) and its project partners, Kuka Industries and Braun/P&G, develop novel technical approaches and procedures for modern telemaintenance. The term 'telemaintenance' hereby refers to the integration of computer science and communication technologies into the maintenance strategy (Chowdhury (2011)). It is particularly interesting for high-grade capital-intensive goods like industrial robots. Typical telemaintenance tasks are for example the analysis of a robot failure or difficult repair operations. Currently the service department of Kuka Industries is responsible for the worldwide distributed customers who normally own more than one robot. Currently such tasks are offered via phone support and service staff which travels abroad. They want to expand their service activities on telemaintenance and struggle with the high demands of teleoperation especially regarding the security infrastructure. In addition, the facility of Braun in Marktheidenfeld has to keep up with the high standards of Procter & Gamble and wants to minimize the machine downtimes. Like 71.6% of all German companies (Spath (2013)), Braun/P&G sees a huge potential for early information on their production system, but complain about the insufficient quality and the lack of currentness of the data.

2. PRELIMINARY STUDIES

For the development of the prototype, substantial preliminary work has been carried out, which is described briefly in this chapter. After several interviews with workers both at Kuka Industries and at Braun/P&G we defined the teleoperation scenario. Second, we performed several measurements to estimate the Quality of Service (QoS) requirements of the network connection for the services required by the scenario. Finally we combined those elements in a time domain model of the teleoperation process.

2.1 User studies

As the teleoperation was a new field for both of the industrial partners, a user centered design approach was used to create the new scenario. That comprises an iterative process which is based on a broad contextual analysis (Hartson (2012)), including several interviews with workers, video documentation of service processes and the fast development

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and discussion of prototypes. Part of the results of such an user experience (UX) driven process are design informing models like the flow model of the envisioned teleoperation scenario depicted in Fig. 1. Those diagrams help the engineers to understand the working environment and the processes.

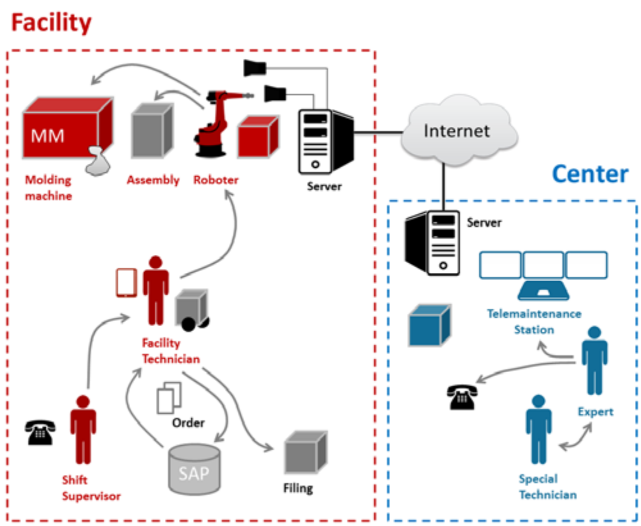

Fig. 1. Flow model of teleoperation scenario

The facility technicians at Braun/P&G are responsible for prohibiting breakdowns of the plant. They need to find the failure and fix it as soon as possible in case a breakdown happens nevertheless. Braun/P&G has a well-trained team of specialists for this purpose, who can handle most occurring problems on their own, but other customers of Kuka Industries may not have such a team. We therefore consider a situation, in which the facility technician is not able to find the failure and cannot fix the problem. His shift supervisor decides to call the customer support of Kuka Industries (depicted on the left side of Fig. 1) to ask for help. An expert connects to the robot and communicates over a mobile device with the technician, so that they both work together to find the failure and fix it. Interviews with both sides also helped us to understand which services are needed to fulfil the scenario:

- *Remote access* to the plant and *teleoperation* of the robot are absolutely mandatory.
- It is crucial to have a reliable human *communication channel* and the possibility of *file-exchange*.
- It also turned out that the workers on both sides consider *video-based interaction* a very important feature. The expert, who knows the robots very well, but is facing the context of the specific plant for the first time, needs appropriate situation awareness. Also, any kind of teleoperation is only feasible with proper feedback information. The technician has a need for videos too, in which the expert explains tasks, the technician has never conducted before.

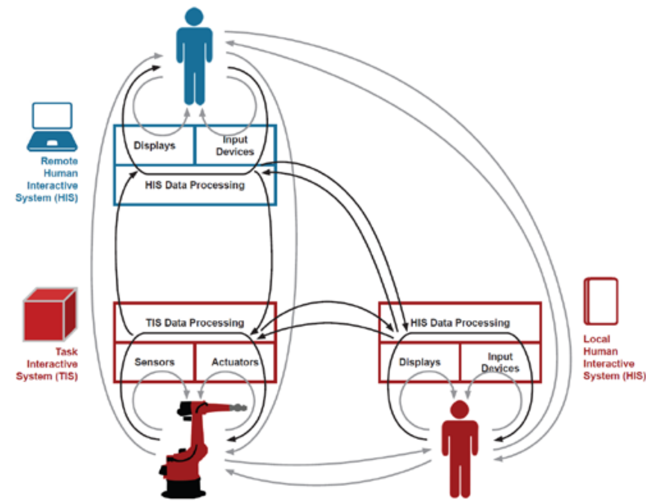

Fig. 2. Extended human supervisory control

Theoretically speaking the teleoperation task can be seen synonymously to human supervisory control as defined in a strict sense in the work of Sheridan (1992). Here the control loop is closed through the human and the control computer. This view will enable us to derive some key process criteria. We extend the model (as in Fig. 2) to the local facility technician. He or she has a very important role regarding safety issues. In Europe and most other parts of the world, nobody gets the legal permission to teleoperate an industrial robot in an automation facility without a local supervisor. In our experiments this service technician always has to explicitly hand over the control to the expert. In the final prototype also the service technician needs to have priority. Therefore he or she also performs human supervisory control and mirrors the conceptual structure of the main teleoperator. For being able to estimate the time domains later, the “human delay” needs to be considered. Humans are known to be much slower than machines. The ‘simple’ reaction time on a button click task is around 215 ms (Kosinski (2008)), but the mean of a human response delay in supervisory control can be much longer (5 to 16 seconds) and depends on the task (Consiglio et al. (2010)).

2.2 Network structure

The setup of a stable and secure communication link between the telemaintenance center at Kuka Industries (or for tests at the ZfT) and the plant at Braun/P&G is essential for the teleoperation scenario. It requires several organizational and technical steps to reach this goal.

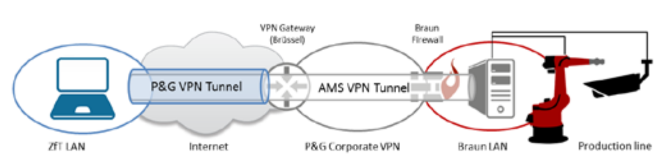

Fig. 3. Network structure