

Conjunction of safety and interaction in an industrial human-robot-collaboration (HRC) environment exemplified by an industrial application

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Abstract— Robot based automation has been done for decades in several industrial fields. Main reasons have been higher throughput and lot sizes, increased quality through repeatability and increasing efficiency in general. Robots have been behind safety fences to avoid any interruption and protect people. Interaction takes place via control panels and just with special trained staff. Full automation is installed where it is reliable on invest. When human-robot-collaboration (HRC) started getting into industry a new kind of automation was born. While in full automation a human serves the automation, in HRC the human gets help from the robot. This occurs complete new challenges. It is not enough developing components in a safe mode, the focus has to be on the process and how interaction between human and robot can take place in a safe and intuitive way.

I. MOTIVATION

The following example shall give an impulse from industry to research about the challenges creating HRC applications in industrial environment. Focus is the conjunction of safety and interaction. It will be discussed by an industrial application example how safety and interaction between human and robot goes hand in hand and which challenges occur when planning a HRC solution. Starting with analyzing the real needs of HRC in automation, over the technical boundary conditions concerning the solution and process itself, the necessary safety regulations till the acceptance by operators and how and which people in industry interacting with robots.

II. DESCRIPTION OF THE APPLICATION

Today automation takes place where high throughput, low varieties and repeatability are necessary. With the technology of HRC, automation in areas where until today no automation has been reliable now becomes reality.

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The application [1] we talk about has not been reliable for automation until today due to high variety, complex sequence of operation. Challenging and ergonomically alarming for the operator is it to lift and install differential cases for the front-axle transmission by himself. With an HRC solution it can be realized that the robot primarily takes over monotonous and physically demanding tasks. The operator now works hand in hand with the robot assistant in a confined space – without any protective fences or additional safety equipment. For this HRC project, experts from KUKA Systems designed a system with efficient use of space through overhead installation and integration into the existing production line without having to redesign it.

III. CHALLENGES OF REALIZING HRC APPLICATIONS

HRC automation brings up new challenges for component companies and system integrators. While in classic automation the boundary conditions and regulations are defined for years, in HRC everything is quite new and with low experiences.

A. When does HRC make sense?

In the very first step there must be analyzed where HRC might be suitable. HRC is not an end in itself. Tasks and workplaces have to be identified where HRC can support humans:

- Workplace with ergonomic issues. Does the operator handle high weight parts? Is the task performed in an unergonomic position?
- Workplace with quality issues. High repeatability of operator task? High error frequency given? Necessity of documentation of the task?
- Workplaces with >100% degree of capacity utilization. Is it possible to avoid work overload of the operator?

B. HRC specific planning basics for a safe automation

When HRC is useful for the process, the priority task of engineering is to design a solution where no human can be harmed by the robot.

Two main contacts between a human and the robot in a HRC automation cell have to be considered:

- Quasi-static contact
- and Free transient contact

can happen within borders, defined in ISO TS 15066.

System integrators have to deliver HRC solutions that are compliant to the machinery directive. For HRC following specialties are necessary based to avoid/reduce contact with the robot to a regulated level:

- The whole engineering process, even at the beginning, has to be HRC compliant and all components have to be checked whether they are suitable for HRC
- Identification of risk for quasi-static and transient contact of the process
- Engineering of a continuous safety concept with definition of necessary safety functions (e.g. safe work spaces...)
- Parametrization and programming of the safety function in the application
- Validation and documentation of all safety functions
- Check of all biometric limits during contact based on ISO TS 15066
- Finalizing Risk analysis and documentation

C. *The human being in the center of HRC automation*

In planning HRC solutions everything is done to make it possible that a human is supported by the robot. Safety is highest priority but the close collaboration between a human and a robot leads to the question of user's acceptance of the robot. Besides ergonomics and design issues, it becomes more and more important to understand and support the user in a human-robot-collaboration with the objective to avoid misuse and increase acceptance.

Different approaches and models identified factors that determine user acceptance of any information technology [2][3][4][5]. These factors could be used as a basis for further research on understanding robot acceptance. Several studies [6][7][8] have already evaluated the acceptance of social robots within an interaction with humans but this does not address manufacturing environments.

As a robot manufacturer with direct contact to customers and users of robotics, KUKA is recently trying to take a closer look at users and their robot acceptance in the HRC. First investigations have shown that a closer examination of factors influencing the user acceptance provides specific data for improvements in developing and designing the robot in a more user acceptable way.

For acceptable robotic design it is also important to know the user group. In manufacturing environments it becomes more customary to have workers with no particular robotics skills and training. Every worker should be able to operate the robot without any comprehensive instruction or technical training. Thus, an intuitive and easy operation of the robot is necessary, not only for easy applications. Robot manufacturers should therefore also concentrate on implementing functions that enable an intuitive handling of the robot.

IV. DISCUSSION

HRC as a new way of automation with limited experience brings a lot of challenges with it. Besides observing the necessary safety standards and using safe components in a HRC solution, it is at first very important to understand for which tasks or workplaces HRC is suitable. The whole engineering process then has to concentrate on developing both a safe hardware solution but also a safe process and interaction between human and robot in the HRC. Furthermore the part of an operator in a HRC should not be underestimated. Working so close to a robot is also new to users and can be frightening, wherefore it is also necessary to consider humans thoughts and feelings while working in a HRC. This can help getting a better understanding of the user group and their robot acceptance in order to avoid misuse and increase the success of HRC. Especially for robot manufacturers a deeper robot acceptance research can provide useful information regarding more acceptable designs and functions of the robots. In summary, this paper shows that HRC is not only about safe technology but also about a safe process and interaction between a human and a robot wherein both of them should be given close attention equally.

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