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Simplifying robot tools by taking advantage of sensor integration in human collaboration robots

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Abstract

Currently, small scale manufacturing is limited to manual assembly due to high product specific costs for fully-automated production. Human robot collaboration (HRC) aims to overcome this problem with semi-automated production by incorporating sensor integrated robotics in more fields of human activity. One key aspect for industrial use of human-robot collaboration is cost efficient adaptability for different manufacturing scenarios. This paper introduces a method that satisfies these demands by simplifying robot tools. Algorithms leveraging the sensor integration of collaboration robots are used to reduce product specific costs. The feasibility of this method is validated by implementation into a flexible screwdriving tool.

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1. Introduction

Human robot collaboration (HRC) has gained a great amount of research effort in recent years. This is due to a large variety of opportunities that come with enabling hybrid workspaces where robots are not separated by safety barriers and are collaborating with human operators. Such workcells enable the implementation of a flexible and reconfigurable production system, where humans handle the tasks that require complex sensing and motions and robots handle monotonous repeated and unergonomic tasks. In this way a production system is achieved that can easily be adapted for different product variants and batch sizes. The advantages of an adaptable production system contribute especially for industries with small scale productions and a wide product variety. Recently, research focused on the technological basics to enable a reliable collaboration, safe and ergonomic for the human operator. This includes vision [1], capacitive [2] or force [3] based sensors for collision avoidance and interfaces or algorithms for simple robot control such as barehanded teaching, voice commands [4] or gestures control [5]. Despite all these advances and innovations it has not yet come to an extensive introduction of the HRC concept to production environments [6]. Besides challenges with certification of safety functions and operator acceptance, there are also concerns in economic operability. This is due to investments for hardware, which can be very expensive in case of human collaboration robots and engineering. There are still no standardized application scenarios; workcell designs must be developed individually and cost are increased. An important factor to advance HRC is therefore the development of robotic tools with standardized interfaces that enable a fast and cost efficient adaptability of workcells for different tasks and product variants. Such tools have not yet been the focus of research and will be addressed in this work. Since human collaboration robots usually entail a wide field of integrated sensors, they enable the opportunity to develop standardized tools that take advantage of those sensors. By using those integrated sensors, tools can be designed, which are technically much simpler than conventional tools for automation and tool costs can be reduced. In this paper a framework is proposed that will help to methodically develop such simplified tools for human collaboration robots and thus ensure the profitability of HRC in future applications.

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2. Hardware and recent applications for human-robot collaboration

State of the art robotic systems enable HRC particularly through the use of sensitive force / torque sensors in the drive units of the robot axes. The torque of every axis is constantly measured during movement of the robot and collisions can be detected. A difference between the measured torque and a variable with the acceptable value stored in the control system directly triggers the robots safety brakes [7]. The selection of a suitable robot is generally based on the technical specifications of the application to be implemented. Currently, there are six considerable industrial suppliers of HRC-enabled robot systems, which have a certification for industrial application on the German market: KUKA (LBR iiwa), Fanuc (CR-35-iA) Universal Robots (UR3/5/10), ABB (previously Gomtec - Roberta), MRK-Systeme (KR5 SI) and Bosch (APAS) [8]. The systems differ in workspace (up to 1,3 m), repeatability (down to 0.08mm), payload (up to 35 Kg), integration of grippers or multiturn axes and in the integration of additional sensors. Such sensors include vision sensors, 3D area sensors [9] or tactile sensor skins [3] they can be used for the detection of parts for visual servoing [10] or as additional safety feature. A recent development that has not yet been implemented in industrial robots are safety features based on capacitive sensors. Hoffmann et.al. for example developed a capacitive based safety system, to detect humans and static obstacle in close distance to the robot [11]. Since a collision can be detected reliable at an early stage, the speed of robotic movement can be increased in HRC workspaces. Not all sensors that have been developed for HRC are directly integrated into the robot. Some applications integrate additional vision sensors into the workcell to enhance the scope of application. Such systems can be used to detect humans and object in a larger area of the workspace and dynamically adapt the speed according to the distance of the object. A further possibility of such systems is the implementation of online path planning to avoid collisions in advanced by adapting the robots motion sequence [1, 12]. One example for an industrial system that enables the implementation of such applications is the “SafetyEye“ from Pilz GmbH & Co. KG [13].

Recent industrial applications include MRK-Systeme „KR5SI“ robots that are assisting workers in assembly operations at Audi AG by handing coolant expansion tanks in order to optimize ergonomic issues [14], UR 5 robots that are used at the Volkswagen plant in Salzgitter for cylinder head assembly [8], UR 10 robots that are used at BMW for collaborative door sealing [15], Bosch „APAS“ robots handling actuators and sensors at Volkswagen Sachsen [8] and conventional robots expanded with vision-based safety stems at Audi Neckarsulm for acceptance testing for industrial robots in HRC settings [8]. All these applications have in common that they have been development individually with high development cost. To optimize the development process for HRC, more research for standardized platforms, tools and interfaces is necessary.

3. Development approach for simplified robot tools used in human-robot collaboration

The development of tools for human robot collaboration requires the contemplation of aspects and constraints that go beyond the considerations for conventional robotic tools. Figure 1 shows a framework for methodological development of tools that takes this factors into account.

One of the most important factor is the safety aspect. Since humans have to interact with the robots, the tools have to be designed to prevent injuries and integrated in the overall safety concept. The next aspect is the tool cost reduction. Since HRC is mainly used in frequently changing production scenarios, the adaptability for different task must be more cost-efficient then in conventional automation. This is on the one hand achieved by leveraging the sensor integration in HRC robot and on the other hand by developing control algorithms for HRC which can be reused for similar subtask in different applications. The last aspect is the adaptability for different production scenarios. This is achieved by using standardized interfaces while integrating the tools in the HRC workcell. The development process is always affected by the entire workcell design, such as the safety system, the robotic controller, or the human-machine interface (HMI). However, those systems are not the focus of this paper, but are respected as boundary conditions for the tool development.

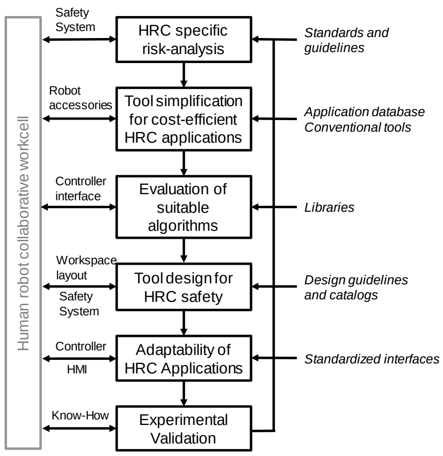

Fig. 1. Methodological framework for the development of HRC tools

3.1. Tools specific risk analysis

As a first development step, for HRC tools, it is necessary to verify that the tool can be used in the worst case scenario of a collision. A collision between a collaborative robot and a human leads to injuries of the affected parts of the human’s body, while the components of the robot or the tool is usually not deformed. The potential degree of injury depends on the type of contact (transient/static), the effective robot mass and speed, the duration of impact, the collision surface area and the