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Intuitive work assistance by reciprocal human-robot interaction in the subject area of direct human-robot collaboration

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Abstract

The paper focuses on the interaction in human-robot collaboration. On the one hand, the robot assistance system individually aligns itself to the employee and on the other hand, the employee gets an interface which enables him to influence certain robot positions. The aim is to support the employee in assembly tasks. The employee's personal anthropometric data and age-related as well as temporary restrictions in movements are considered by being recorded individually via motion capturing before the workplace is built in a virtual and real environment. Based on the data, task specific movements of the employee are simulated using digital human models for the virtual representation of the employee, combined with an ergonomic analysis within the work environment. The impact of the employee on the assistance robot system is provided by the design of intuitive user interfaces. The positioning of the components in the assembly is done user-specifically by the robot. In addition, the employee gets a graphical user interface and can additionally adjust the position or turn the components. In this paper, preliminary results of this ongoing research project are presented as well as two reference processes from the field of assembly technologies as application examples.

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1. Motivation

The individual design of workplaces constitutes a prerequisite for its human-centered, ergonomic and wholesome planning within industrial production. In this context, especially flexible and adaptive assistive workplace devices with respect to the emerging field of human-robot collaborations should be taken into consideration. One major motivational aspect is the demographic development throughout European countries and its corresponding increase of the mean age of the workforce. According to the aging report of the European Union, nearly one third of the population will be 65 years or older by 2060. With respect to the working age population, defined by the range between 15 and 64 years, a decline from 67% to 56% is predicted [1]. The Federal Statistical Office of Germany reports that by 2060, a substantial percentage of the work-force will be at the age of 50 or above [2]. By considering the different diagnostic subgroups that make up for the expenses and loss of production due to work inability, 23.4% can be assigned to musculoskeletal disorders (12.4 billion Euros) [3]. This sociodemographic development arouses both opportunities and challenges that need to be met within industrial engineering processes and future developments as well as assembly technologies and systems [4].

When addressing workplace design related issues, the virtual planning of such assembly processes becomes increasingly important. One aim in this context is the virtual planning of joint workplaces of humans and robots and its subsequent implementation and realization in actual industrial work environments. A major motivational aspect for an interaction between humans and robots is the intention to combine the flexibility of manual processes by humans and the high efficiency and repeatability of automated processes in manufacturing and assembly systems. These systems benefit from the synergistic effects of a collaborative scenario between humans and robots [5,6,7].

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For the virtual workplace planning and product development processes digital human models (DHM) are used in order to simulate characteristics and capabilities of future users or employees respectively [8,9]. These different characteristics of employees are subject to an increasing intra- and interindividual variance, employee's physical work capacity as well as different capabilities and skills due to the aforementioned demographic development [10,11,12]. Whereas the rising importance of the virtual planning of joint workplaces of humans and robots [6,13,14] was stressed in the literature, the intuitive and individual character of these workplaces still needs thorough investigation.

Hence this conference contribution fosters the investigation of an issue that needs further consideration within the field of industrial engineering, assembly technologies and direct human-robot collaboration, foremost with respect to its virtual planning process. It describes an overall concept for the individual and virtual planning and design of human-robot-collaborations and the realisation of reference processes including the interfaces for the employees.

2. Method to design individual work assistance

In the field of assembly, there are different approaches to make tasks feasible. For this, different technologies are used such as machines, handling or lifting devices which include automats, telemanipulators and balancers [4]. However, the application of these devices is laid out to strictly restricted tasks. To adapt an assistance system to the employee's needs a highly flexible system is required.

The realization of a human-robot collaboration in assembly tasks offers the possibility to implement an assistance system that can react to both given and varying constraints resulted by the employee or by environmental influences.

There are many approaches to human robot collaboration for industrial applications. Research projects address the interaction of humans and robots in workspaces without separating safety devices using simulations as a planning method [15]. Even in the field of assembly tasks there are approaches of direct human robot collaborations [16] with planning of appropriate assignments of tasks, supplemented by evaluations of ergonomics and feasibility of the assignments in a simulation [17]. Although there is a division of tasks between humans and robots and a predetermined sequence of execution of working tasks in these applications of current research projects, there is no consideration of the employee's individual performance paramters to design the work place orientated to personal capabilities and ergonomics.

However using robots as a supporting element in the work system provides the opportunity to adjust the degree of assistance based on a variable automation level and respond to human restrictions individually.

The human-robot collaboration system affects the workflow and the distribution of work contents through the intervention of robots in work tasks. Thus, an influence arises on the execution of the employee's work tasks by the robot. To account for this interaction, data need to be generated in advance in order to optimise the collaboration between humans and robots. The robot-based assistance system aligns itself automatically to the employee by an analysis of the data. Moreover, the employee has an impact on the type and the extent of the robot's influence by the possibility of making modifications on subsequent fine adjustments.

Adapting workplaces to the employee's individual demands requires a highly changeable assistance system that allows a quick and self-influenced set up to the employee's needs. These needs are immensely affected by the ratio between both prescribed physical minimum requirements of the work tasks and the employee's performance parameters. The physical minimum requirements include for example deliverable forces or mandatory body postures to fulfil the work tasks. If these requirements are on a higher level than the employee's individual performance parameters, the execution of the tasks is not bearable or even feasible and can thus lead to or aggravate physical harm. For an optimised workplace design and to avoid health critical work contents, the robot based assistance system is supposed to support the employee based on his individual prerequisites and capabilities.

To ensure a human-robot collaboration with interaction opportunities including the possibility to affect the assistance

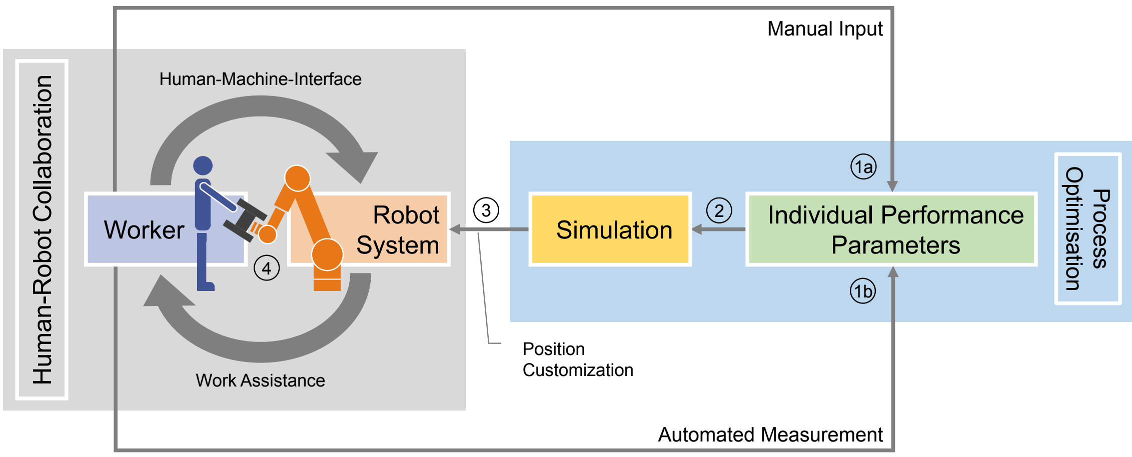

Fig. 1: Method for designing an individualised, robot-based assistance system