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Wholistic Human Robot Simulation for Efficient Planning of HRC Workstations

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The planning of assembly workplaces with direct human-robot collaboration (HRC) is a complex task owing to the variety of target criteria that must be considered. The lack of a digital simulation tool for the wholistic planning and safeguarding of HRC-scenarios, as well as a lack of adequate training and qualification concepts for companies, are currently inhibiting the implementation of HRC. We are developing a new way to digitally design collaborative assembly systems to help companies embrace HRC systems.

In the context of globalisation, manufacturing companies face new challenges. A growing diversity of variants of industrial components, shorter product life cycles and fluctuating demands require versatile production systems in order to secure the competitiveness of companies in high-wage countries in the future. Cost-effective assembly is an important lever for economic efficiency. Since investment-intensive and sometimes inflexible fully automated solutions are often limited in their ability to enhance productivity and efficiency, the topic of human-robot collaboration (H RC) is becoming increasingly important. The aim is to combine the strengths of the human (flexibility, intuition, creativity) with those of the robot (strength, endurance, speed, precision) to use resources efficiently and thus to increase productivity.

Previous implementations of HRC have failed to take full advantage of the potential for humans and robots to cooperate, owing partly to the complexity of the processes to be planned and partly to a lack of suitable methods and tools [1]. Simulation tools make it possible to visualise complex issues in advance and make them plausible, for example, in terms of feasibility, accessibility and space requirements without the use of costly prototypes. Various systems already exist in the market, which focus either on the simulation of manual workstations with digital human models or on the simulation of automated workplaces with partly manufacturer-specific robotic libraries. A few systems support the prototypical usage of a human model in simulation software for robotic systems for individual tasks. In order to meet the requirements for a wholistic HRC simulation for the various fields of activity of assembly, a combination of both simulation systems is necessary – but this is not supported by available software solutions [2].

The goal of the collaborative research project KoMPI [L1] is to develop a new method for the integrated planning and implementation of collaborative workplace systems in assembly with different product scenarios. This essentially comprises three components shown in Figure 1. The main part is the development of a wholistic, digital planning tool. On the basis of a potential analysis of the work system carried out in advance, the automation, technical and economic suitability, ergonomics and safety can be simulated and evaluated. The second component comprises developing a concept for the participation and qualification of the involved employees in order to integrate them early in the planning process and thus to ensure their acceptance. The third component is the implementation of HRC application scenarios for the respective partners to use and the associated validation of the planning tool.

The main task of the development of the performance-based, digital tool is the integration of human model and robot simulation systems. The human behaviour simulation is done using the software Editor of Manual Work Activities (called "ema") [L2] developed by imk automotive GmbH. It is a wholistic planning method based on a digital human model, which autonomously executes work instructions based on MTM-UAS. An interface between ema and the open source software framework Robot Operating System (ROS) will enable ema to simulate robots, sensors and their environment with the help of a wide range of drivers [3].
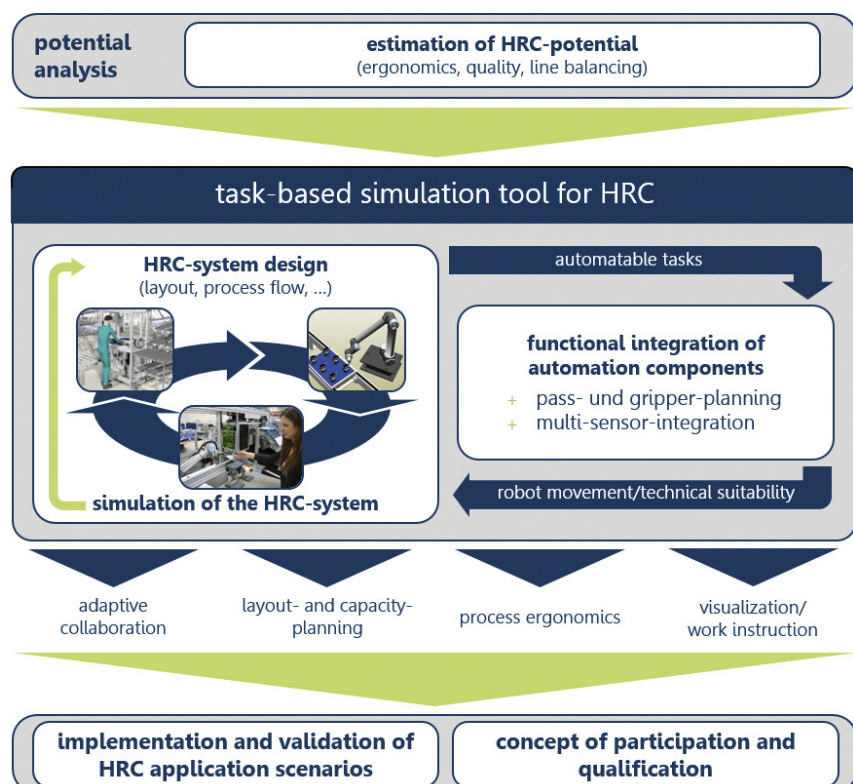

Figure 1: Three stage implementation procedure of the proposed HRC system.

The software called ema, enhanced with appropriate functionalities, will form the basis of a system that will help with the wholistic planning of HRC workplaces. In addition to the functions for the human model, parametrisable tasks for automation components are developed, which allow a flexible allocation of work tasks between human and robot. In addition to the libraries for human models, robots, sensors and environment objects, a grasp library is also implemented in order to make a statement about the feasibility of the automation tasks. The interface to ROS also enables collision-free path planning, taking into account human movements and the entire environment [4]. The design and safety guidelines of ISO TS 15066 are also taken into account. Including all HRC operating modes (safety-rated monitored stop, hand guiding, speed and separation monitoring, power and force limiting), a sensor library and the logical link to objects, taking the corresponding safety distances into account, allowing the creation of a safety concept. For example, the output of collision and contact forces as well as the maximum valid speed limits of the robot support the planner in the risk assessment. In order to meet the requirements of the planning task, decisive information on the economic, ergonomic and safe operation of a HRC system can be generated before implementation.

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Links:
[L1] www.kompi.org
[L2] www.imk-ema.com

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[4] K. Lemmerz et al: "Functional Integration of a Robotics Software Framework into a Human Simulation System", in ISR 2018.

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A Cognitive Architecture for Autonomous Assistive Robots

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Effective human-robot interaction in real-world environments requires robotic agents to be endowed with advanced cognitive features and more flexible behaviours with respect to classical robot programming approach. Artificial intelligence can play a key role enabling suitable reasoning abilities and adaptable solutions. This article presents a reseach initiative that pursues a hybrid control approach by integrating semantic technologies with automated planning and execution techniques. The main objective is to allow a generic assistive robotic agent (for elderly people) to dynamically infer knowledge about the status of a user and the environment, and provide personalised supporting actions accordingly.

Recent advances in robotic technologies are fostering new opportunities for robotic applications. Robots are entering working and living environments, sharing space and tasks with humans. The co-presence of humans and robots in increasingly common situations poses new research challenges related to different fields, paving the way for multidisciplinary research initiatives. On the one hand, a higher level of safety, reliability, robustness and flexibility is required for robots interacting with humans in environments typically designed for them. On the other hand, a robot must be able to interact with humans at different levels, i.e., behaving in a "human-compliant way" (social behaviours) and collaborating with humans to carry out tasks with shared goals.

Artificial intelligence (AI) techniques play an important role in such contexts providing suitable methods to support tighter and more flexible interactions between robot and humans. In this very wide area, there are several research trends, including social robots, assistive robots and human-robot collaboration, which focus on the co-presence and non-trivial interactions of robots and humans by taking into account different perspectives and objectives.

The Planning and Scheduling Technology (PST) Laboratory [L1] at the CNR Institute for Cognitive Science and Technologies (ISTC-CNR), has considerable know-how on this important research topic. The group has worked on several successful research projects that represented good opportunities to investigate innovative AI-based techniques for a flexible and safe human-robot interaction. Specifically, two research projects warrant a mention: (i) GiraffPlus [1, L2] is a research project (2012-2014) aimed at the development of innovative services for long-term and continuous monitoring of senior people using sensor networks, intelligent software and a telepresence robot (the Giraff robot). PST developed novel techniques to provide personalised healthcare services through the system to support seniors with different needs directly in their home. (ii) FourByThree [2, L3] is a recently ended H2020 research project [2014-2017] whose aim was to develop novel software and hardware solutions (from low