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ScienceDirect

Procedia CIRP 44 (2016) 210 – 215

www.elsevier.com/locate/procedia

6th CIRP Conference on Assembly Technologies and Systems (CATS)

Process-oriented task assignment for assembly processes with human-robot interaction

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Abstract

Many assembly processes, particularly in the manufacture of large components, are still carried out by humans manually. In addition to rationalization aspects, high quality requirements, non-ergonomic activities, the lack of well-qualified workers etc. may require the use of automation technology. Through novel possibilities of human-robot-cooperation these challenges can be met through a skills-based division of labor. In this article an approach to process-dependent task assignment to human or robot is presented. The approach is based on a detailed analysis of the skills of humans and robots, in order to bring it into balance with the required product and process characteristics.

Peer-review under responsibility of the organizing committee of the 6th CIRP Conference on Assembly Technologies and Systems (CATS)

Keywords: Physical human robot cooperation, skills, task assignment, assembly planning

1. Introduction

Against the background of globalized markets, maintaining the competitiveness of manufacturing companies in high-wage locations is an ongoing challenge. Highest quality requirements, the ability to respond quickly to market challenges, the control of variety as well as the reduction in production costs are the key strategies in order to survive on the market [1]. Until today, the assembly has over other areas a high proportion of manual work on the production [2]. Particularly in the area of large component assembly there are great potential for rationalization [3]. However, these do not consist in automating a maximum number of processes, as was the case in the 90s [4]. Current assembly concepts pursue the objective of „customized automation“ [5]. Through the ability of robotic systems to work in cooperation with humans, a whole new area of application in automation has exceled over the last years [6]. The decision for or against an automated process no longer needs to be carried out for each basic task, but instead can be specified up to specific tasks according to the specific human, respectively robots, skills [7]. Thus, tasks can be assigned needs-oriented and respond flexibly to changes in the state of production, all depending in the availability of equipment [8]. Planners are confronted with the challenge of a preferably efficient resource management in the context of reconfiguration planning or changing boundary conditions. Thus a skills-oriented assembly sequence planning is essential [9].

Previous papers on this issue have modeled extensively a high number of possible assembly sequences and mapped them, supported by software, on possible cooperation types. In practice it turns out that the predominant number of human-robotic-cooperation forms (HRC) are executed in autarkic or synchronized operation. Cooperating and collaborating operation forms have hardly been implemented mainly due to the difficulties in safeguarding the processes.

This article presents a method which deduces the assembly sequence planning from the product and the process to the production equipment through a determination of a system configuration in order to implement a simplified skills-oriented assembly sequence planning for autarkic and synchronized HRC-operating modes. Subsequently, the

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doi:10.1016/j.procir.2016.02.080

method is validated using the example of an assembly process of the aircraft industry.

2. State of the art / Related work

The state of the art still corresponds mostly to the strict separation of working spaces of humans and robots. Through the market availability of a new robot generation which should be qualified for the direct human-robotic-cooperation due to a reduction of kinetic energy, a two-channel monitoring of the control as well as to different sensor concepts for collision avoidance, the concept of HRC has gained momentum.

Thiemermann described, as Fig. 1 shows, the potentials that could be exploited through HRC [8].

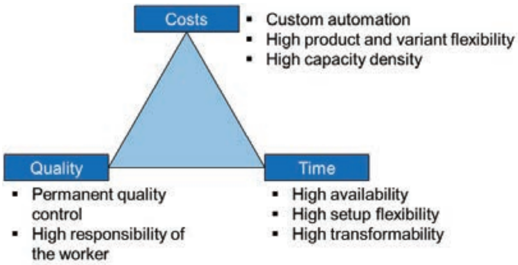

Fig. 1. Potentials for Human-Robot-Cooperation [8].

There are now a number of producers with different models on the market. Some of the most prominent representatives are the budget-priced UR5 respectively UR10 from Universal Robot, the two-armed YuMi from ABB, the APAS from Bosch, which is equipped with a capacitive skin, as well as the LBR iiwa from Kuka, which disposes of highly sensitive force-torque sensors in all axis. As industrial robots always constitute an incomplete machine, becoming only complete in combination with peripheral devices, like grippers, tools, sensors etc, according to DIN EN ISO 10218, they can be assessed against the background of a defined application scenario. Thus, the implementation of HRC critically depends on whether the necessary security conditions can be met [10]. The preview of the TS ISO 15066 at this stage provides the specification for risk assessment procedures and supplies technical and biomechanical limits and guidelines for the technical documentation of HRC. Here, the specific features of robots designed to work with humans are taken into account [11].

Regarding the type of cooperation between humans and robots, Thiemermann distinguished four operating modes, as shown in Fig. 2 [8]. The temporal and spatial separation of the work of humans and robots represents the current state of technology. Working humans and robots at the same time, but spatially separated so there is an autarkic operating mode, since the work content can be matched to each other. Working at the synchronized operation form, humans and robots execute their tasks after each other in the same workspace. A cooperating operation form is used when humans and robots work simultaneously in the same workspace.

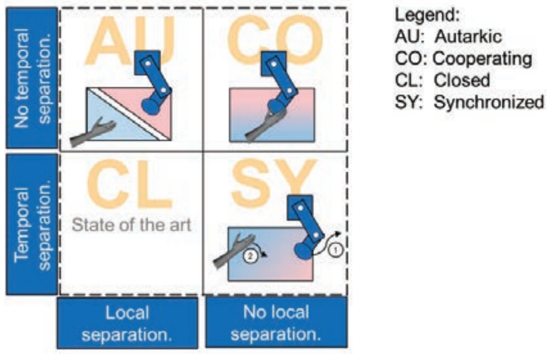

Fig. 2. Types of Human-Robot-Cooperation [8].

A special form is the simultaneous execution of a common task. This hand in hand work is called collaboration. In the literature, this term is often also used as a collective term for HRC. The cooperation of humans and robots enables the use of the respective advantages of these resources. The linking of these factors, shown in Fig. 3, is the goal of HRC.

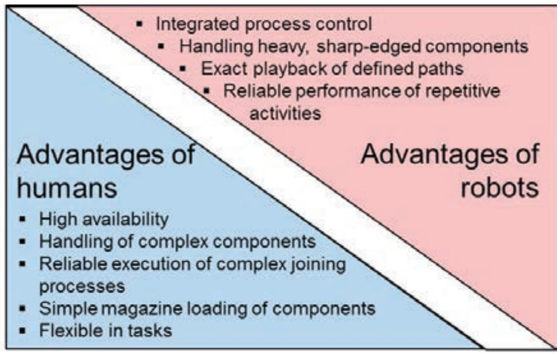

Fig. 3. Advantages of humans and robots [12].

Meanwhile, there are increasing pilot projects in the industry which want to use these accumulated benefits [13,14,15]. In most cases, pilot projects are laid out to sequential operation forms. At Audis production plant, a robot takes components from a box and hands it to the human at an ergonomic level [15]. These forms of direct interaction are very rare, by now.

The decision on who has to do what work units shall be taken in the assembly planning. Current research efforts are aimed to use the information that is generated in the assembly planning procedure consistently throughout the real assembly stations. For this descriptive models are developed, linking the virtual world with the real planning assembly system [16].

In planning this description models will ensure the compatibility of product requirements and skills of the equipment to perform the required assembly processes [17].

This comparison can be extended useful to the skills of the human resource. In relation to human, however, it's important to assure that the resources are used in the context of ergonomically acceptable limits. To take account of this principle, digital human models are integrated into planning