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Implementation of virtual reality systems for simulation of human-robot collaboration

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A collaboration between human and robot can implicate many advantages for complex industrial assembly processes, especially as increased flexibility and adaptability become a key feature of production systems. The use of virtual reality (VR) systems has the potential to simulate cooperative processes in advance and to include workers and their individual behavior into the simulation. The use of VR simulations makes it possible to secure processes and reduce physical and mental barriers between human and robot. This paper presents a methodical approach for the implementation of systems for the virtual testing of collaborative assembly processes. Following the aim of replicating the assembly process with the highest possible immersion, a specific VR system is derived from an analysis of the assembly process. Core features of the system are the physical simulation of the assembly process, the integration of the robot control and a haptic feedback for the operator.

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Keywords: Virtual Reality; Simulation; Human-Robot Collaboration

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1. Introduction

The collaborative assembly fills the gap between fully automated production systems and manual assembly with high flexibility. This is in line with current competition requirements, that force companies to adapt at any time to changes on the market. However, there are great uncertainties about the economics and safety of these systems. Virtual reality (VR) offers the possibility to analyze a collaborative assembly system in relation to these risks. It has been shown, that VR offers the possibility to visualize complex objects as for example in pilot training on flight simulators [1].

The basic idea of these applications is to enable a model of work processes or products without building a physical prototype since the latter are costly and only possible to create at the end of the design process. VR-systems allow to carry out analyses of the object already at the design phase. During the examination of work processes in VR, in addition to the time and cost savings, the safety of the test person is ensured. In this case, the installer is not exposed to any danger by unsecured processes, since only virtual work is performed [2]. In order to achieve a realistic image of collaborative assembly in the VR, various components are required that allow the user to immerse into the simulation. VR systems are currently being developed on the basis of other VR applications [1]. Following the aim of replicating the assembly process with the highest possible immersion, a specific VR system is derived from an analysis of the assembly process.

2. Virtual testing of collaborative assembly processes

VR has evolved over the last four decades and is, according to the National Academy of Engineering, one of the 14 major technical challenges of the 21st century [3]. As today, VR is used in a wide range of applications including medicine, industry, military, biology, meteorology and architecture [3] [4]. In industrial applications it is mostly used to ensure product quality while reducing time in product development [5].

Due to the numerous fields of application for product development, a further distinction must be made within these. Each sub-area of product development can achieve specific advantages through the expanded view in VR [6] [7]. The two scenarios proof of concept and training are described in more detail.

The term proof of concept summarizes the review and the analysis of different processes in product development. These generally include assembly, assembly systems, maintenance, production and production planning. VR can support the understanding of the processes and the determination of parameters and variables based on the simulation. The feasibility, risk and error analysis as well as the working conditions of the process are examined. By answering questions on manufacturability, ergonomics, process times and risks, the quality of the process as well as the product can be improved. At the same time, possible errors can be detected and prevented in the planning phase. [6] [7] [4] In [5], two applications in the field of assembly are described. The first application simulates the assembly of a train cooling system. Within the scope of the simulation, the entire assembly process is examined with regards to feasibility. The second application simulates the dismantling of an aircraft landing gear. The simulation was carried out to examine the maintenance of the aircraft landing gear during the first design phase. Therefor, the steps of the disassembly were first identified, in order to subsequently determine the optimum sequence. The two systems do not include any robot-required safety techniques for cooperation between humans and robots. Still, various assembly activities that are described in connection with the handling of components and tools can be used as an input for the planning of collaborative assembly.

Workflows are often trained in the real production environment. Since the skills that are required for efficient work still need to become teached, this can lead to reduced productivity. New workflows can be tested beforehand using a virtual work environment. Thus, the skills required for efficient and safe work are obtained without impeding production or consuming material. There is also the possibility to test dangerous processes without risk. This can be used to prevent accidents and reduce their number. According to [8], training in the VR can achieve even better results than a traditional training, if the virtual process is similar to the real process and this conformity is perceived by the user [6] [5] [7] [9].

In [10], the development of a training system for human-robot collaboration in VR is presented. The simulated process is the collaborative handling of carbon fiber mats for the production of fiber composite components for the aerospace industry. A robot is responsible for picking up and transfering a carbon fiber mat and handing it over to a