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ScienceDirect

Procedia CIRP 37 (2015) 152 – 157

www.elsevier.com/locate/procedia

CIRPe 2015 - Understanding the life cycle implications of manufacturing

Method for an enhanced assembly planning process with systematic Virtual Reality inclusion

Pascal A. Winkes[a,*], Jan C. Aurich[a]

[1]FBK – Institute for Manufacturing Technology and Production Systems, University of Kaiserslautern, Kaiserslautern, Germany

* Corresponding author. Tel.: +49-631-205-3224; fax: +49-631-205-3304. *E-mail address:* pascal.winkes@mv.uni-kl.de

Abstract

The use of Virtual Reality (VR) technology is a promising approach to eliminate crucial problems in assembly planning.
This approach presents an enhanced assembly planning process with valuable integrated VR assistance for a definite structured detection of planning failures. It integrates the VR validation of the assembly in a workshop after the specification step of the assembly planning process. Detailed holistic instructions for the workshop preparation and the VR use are given. This includes a data flow model, hardware requirements and the workshop team structure as well as testing the single assembly steps and the detection and evaluating of planning failures. Further, a procedure for improving those imperfections during the VR workshop is developed. Changes will be written back into the specifications book and the planning will be implemented in the physical factory. This leads to an enhanced detection and improvement of planning failures before the realization of a new assembly station.

Peer-review under responsibility of the organizing committee of CIRPe 2015 - Understanding the life cycle implications of manufacturing

Keywords: *Assembly planning, Virtual Reality, improvement*

1. Introduction

1.1. Assembly planning and Virtual Reality

Assembly planning is an important factor for the success of a company. During the planning process of the assembly line, changes can still be carried out with little effort. But often failures are only recognized, when the new assembly is implemented and already running. Changes after the implementation are very expensive [1, 2]. This problem is drastically increasing with the future trend of shorter development times and higher flexibility and complexity [3].

The early recognition of planning failures before the physical realization can be enhanced using digital tools. Especially a Virtual Reality (VR) system is very promising regarding manual assembly. An assembly area can be visualized, simulated and tested virtually close to reality [4, 5]. VR is a computer technology for generating and visualizing a virtual environment. To a certain degree, the users get a feeling of being part of this environment and interact with it in real-time. The main features of a VR are immersion, interaction, and imagination [6].

1.2. Related Work

In the past years, various publications described how VR can be used for assembly planning tasks. The majority concentrates on the VR use and special technical problems.

Connacher et al. [7] described first possibilities for the use of Virtual Reality techniques including assembly tasks and presented a VR prototype. Reinhart et al. [4] further proposed that VR has a great potential for the support of complex manual assembly planning tasks. This potential could be used with 3D projection and haptic input devices. A virtual workbench for assembly tasks with realistic haptic feedback was presented by Fröhlich et al. [8] whereas Bennis et al. [9] developed a method

Peer-review under responsibility of the organizing committee of CIRPe 2015 - Understanding the life cycle implications of manufacturing
doi:10.1016/j.procir.2015.08.007

to project a virtual model of the human user in the VR. Rossmann et al. [10] used a sophisticated virtual human model to analyze the ergonomic conditions of manual workplaces. VR combined with production simulations was presented by Schenk et al. [5]. They used this combination for assembly visualization and workers training. Workers could choose the perspective for an assembly simulation. This enabled them to better understand how to deal with difficult assembly tasks. Similar advantages were stated by Blümel et al [11]. In his dissertation Zachman [12] investigated in the VR if a certain assembly step of a part was "difficult" or "easy". He also proposed to train workers. They could regard the assembly process in the VR from freely selectable perspectives. In a second step they performed the virtual assembly task themselves. Several researches were comparing virtual and real assembly tasks, often using haptic feedback. Jayaram et al. [13] performed assembly processes in the VR and compared them to real assembly processes. They used constraints and collision detection for their simulation. Still they realized that virtual tasks take a longer time than their real counterpart. Garbaya et al. [14] made experiments about simple assembly tasks. They concluded that haptic feedback brings a great benefit. Lim et al. [15] did simple assembly tasks and compared haptic and non-haptic input with the same movements in reality, where haptic input was much closer to reality than non-haptic. Seth et al. [16] suggested a physics-based VR with haptic interactions. The aim was to analyze an assembly before building real prototypes. The 3D visualization promised better results than common 2D visualization. A concept moving the whole assembly process in the VR was presented by Goldhahn et al. [17]. However, the focus in most publications was on an improved stereoscopic view, on haptic feedback or on possible benefits for special tasks of the VR.

1.3. Research Gap and Objectives

Following insights are derived from the previously described researches: Several approaches were described for the use of VR during assembly planning. They explain different technical aspects and possibilities of the VR. But there is no proper implementation in the assembly planning process and no definite description of the VR supported process. It is important to use the VR only for planning steps where it is really needed for better benefit and not for steps, where common computer programs already do good service and the VR could not do better. As the VR workshop should reveal planning mistakes, the VR will be used when all planning for the new assembly has been done, but is not yet carried out. For the planning process following Lotter [3] this will be just after finishing the specification sheet. Moreover a clear and structured process for the VR use is needed, to guarantee a benefit for the assembly planning process. After the review of existing literature the objective of this research is to develop a concept for structured and valuable use of the VR during the assembly planning process. Core of this concept is the innovative VR workshop. During this workshop the planned assembly will be tested, rated, and optimized. It will be described in which order the assembly steps have to be performed and rated. The rating and detection of planning failures becomes more objective by using a given rating scheme. Further there will be a procedure for failure erasing. Instructions to each step will be given. In addition, the VR workshop will be integrated in the assembly planning process. Here, preparation orders will be given. They will include the connection between the assembly planning process and the VR workshop, especially the data flow including data preparation and generation of the VR model. Moreover, the objectives of the workshop will be determined and a workshop-team will be arranged. Last, the recirculation of the results of the VR workshop will be clarified. The joining step itself of an assembly can be simulated with special calculations and programs. In this research, the focus is set to the following steps of a manual small-parts assembly: Reaching out to an assembly object, grabbing, and bringing the object (compare Lotter et al. [3]). Virtually performing and rating those steps during the VR workshop outlines a new way of validation and improvement of manual assembly stations.

2. VR workshop concept

Before the VR workshop can be executed, several prerequisites and preparations have to be fulfilled. Those are described in chapters 2.1 to 2.5. Chapter 2.6 explains the procedure of the VR workshop itself.

2.1. VR system

In order to run the VR workshop, several prerequisites regarding the VR system have to be fulfilled. The interfacing components of a VR can be divided in input and output devices. Input devices are needed for the interaction with the virtual environment [18]. Most common is the use of a flystick (see Fig. 1) in combination with tracking markers and cameras. It is possible to navigate through the virtual environment by dragging the flystick. The user can select and manipulate objects with a virtual beam projected in the virtual environment. Using data gloves, even more realistic interaction becomes possible, especially if haptic feedback is given [6, 19, 20]. Still the usage of a common flystick is sufficient for the tasks of the VR workshop. Output devices address the human senses. Most important is the visualization. For a realistic visualization, 3D projection is mandatory. The size and design of the output devices is very important for a good immersion.

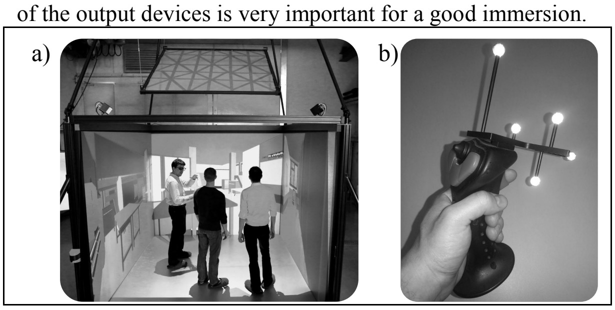

Fig. 1. (a) CAVE at the FBK; (b) flystick

A Powerwall consists of a large screen, so several people can visualize the virtual environment life-sized. A CAVE (Cave Automatic Virtual Environment, see Fig. 1) is even more