Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 62 (2017) 547 – 552

www.elsevier.com/locate/procedia

10th CIRP Conference on Intelligent Computation in Manufacturing Engineering - CIRP ICME '16

Design of a test environment for planning and interaction with virtual production processes

Christian Buchholz[a,*], Simon Kind[a], Rainer Stark[a,b]

[a]Technical University of Berlin, Pascalstrasse 8-9, Berlin, 10587, Germany
[b]Fraunhofer IPK, Pascalstrasse 8-9, Berlin, 10587, Germany

* Corresponding author. Tel.: +49 030 39006 111; fax: +49-030-39006-246. E-mail address: c.buchholz@tu-berlin.de

Abstract

Rising complexity of systems combined with multi-disciplinary development and manufacturing processes necessitates new approaches of early validation of intermediate digital process and system prototypes. To develop and test these approaches, the modular digital cube test center was build. Usage of different Visualization Modules such as Powerwall, CAVE or Head Mounted Display allows immersive interaction with the prototypes. Combined with Haptic Interaction Modules from one axis assembly device to a hexapod simulator up to a full freedom kinematic portal and usage of different simulation modules of vehicle design, multi-kinematic, manufacturing and process-simulation allows early virtual prototypes validation in multiple use cases.

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Intelligent Computation in Manufacturing Engineering

Keywords: Virtual prototypes; Modularity; Early testing; Immersive interation; Haptic interaction

1. Introduction

Today’s production industries are influenced by several megatrends which have a massive impact on its established work processes. New technologies interconnect different research disciplines to generate innovations and result in a rise of the product complexity. Dynamic product life cycles reduce the available production time, in line with rising customer individuality. Furthermore, the augmenting technology diversification necessitates focused specialization of companies and the demographic change forces initiatives to support the qualifications and competencies in production of a growing elderly part of employees [1]. The digital factory, as it describes an early production planning and design of the factory closely coordinated with all corporate processes, is a lever to handle these challenges [1].

Production planning in this context refers to both - the planning of the production processes as well as the planning of the production systems. The aim is to develop and validate products, production processes and production sequences in an early phase of development and to accompany and accelerate the production development with digital models and tools. In a final step, the virtual instruments are utilized to monitor and improve the process excellence in the actual factory on a constant basis [2].

With well-established and stable production processes using a high automation level for assembly, handling and manufacturing processes in general, especially in large scale and mass production, automation changed the activities and position of humans in production processes within the last decades [3]. With the increasing system complexity and inherent unpredictability for the human operator, automized processes tend to generate situations, which are difficult to cope, especially in case of malfunction. This effect is known as the so called “irony of automation” [4]. When focusing onto small series or prototype-production, the intelligent and physical adaptability of humans can rather not been replaced by a highly automated production, ensuring an economic viability [3].

Therefore, the human is still the key element in both: the planning of the production and the production itself, assuming different roles in each step.

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Intelligent Computation in Manufacturing Engineering
doi:10.1016/j.procir.2016.06.085

Virtual reality (VR), as it describes a real or simulated environment in which a perceiver experiences telepresence [5] by using 3D visualization technologies is an opportunity to put the user and its interaction with the production process in focus and gain qualitative user statements [6]. As VR usage is common in industrial practice for certain applications as visualization of an early step planning as e.g. layout design, the opportunities and challenges of VR usage in production planning are inadequately investigated.

With this strategic perspective in focus, the chair of industrial information technology of Technische Universität Berlin performed its research project "Digital Cube Test Center" in order to investigate the VR based interaction of human with the virtual models of digital factory.

This paper describes the development process of the test environment "Digital Cube Test Center" (DCTC) from requirements gathering, through the derivation of solution elements and principles, the development of a test environment architecture integrating these elements to the use case based validation of the achieved results.

2. Analysis and Requirements Gathering

2.1. State of the Art of 3D Model application

In today's applications of digital factory, 3D models are used for different tasks of static, Computer Aided Design (CAD) based modelling activities, various simulations based on these models and validation activities based onto the achieved modelling and simulation results [2]. 3D Models are used at the different production planning object levels from production facility over production system, production machine down to production process [6]. The static activities range from factory layout planning over facility and machine design until tool design.

Usual industrial simulation objectives are load analysis as ergonomic simulation, 3D movement as robot kinematic analysis or assembly simulations, process simulation as numeric control process or CAM simulations and control simulation used to investigate controller behaviour. For validation purposes, virtual reality is used for training and education, visualization for communication and validation purpose e.g. in design reviews, or virtual testing as for maintenance processes [3].

2.2. Requirements Analysis and Gathering

The requirements analysis encompasses the tasks that go into determining the needs or conditions to meet for a new or altered product or project, taking account of the possibly conflicting requirements of the various stakeholders, analyzing, documenting, validating and managing software or system requirements [7]. For the test environment design, thus the different "requirement sources" have to be identified and analyzed in order to extract and determine requirements usable for the test environment design process.

The following requirements sources were identified during analysis:

- State of the art applications of 3D Models for planning purpose. The 3D models are designed and simulated by the human in order to plan the different object levels.
- Requirements from research in the field of planning improvement. The major research question is how to enable the human planner to achieve "better" planning results as they might be achieved in shorter time, in a higher quality or with less resource usage than today.
- State of the art applications of 3D Models for process steps including humans. The 3D Model based process planning includes humans in order to plan its operation in the process. In state of the art applications, usually virtual human models are used for this purpose of "human centred design".
- Requirements from research in the field of achieving better process integration of humans than with today's digital factory simulation tools. Due to the limits of today's virtual human models this research field aims at allowing humans to interact with virtual models. The major research question is how to improve the interaction between a human process participant and a virtual model in order to get more valid test results.
- The usability of the test environment in order to design a test environment that allows easy usage and maintenance by user and operator.

Analyzing, structuring and detailing the requirements lead to the following list of seven top level requirements to be achieved for test environment design (see table 1). Each top level requirement has several sub-requirements which are not shown for reasonable space. The top level requirements are divided in three levels of priorities: Achieving the results that fulfil the first priority requirements will result in a test environment able to perform the state of the art applications of virtual reality. The second and third priority requirements define the area of research to be conducted at the test environment with priority 2 requirements achievable with medium and priority 3 with high effort.

Table 1. Top level requirements for DCTC

	Requirement	Priority 1	Priority 2	Priority 3
1	Opportunity to move though whole production facilities	X		
2	3D Visualization of virtual models from production process to production facility	X	+ in spec. planning software	
3	Simulation of running processes from production process to production system	X	+ Real Time	+ in spec. planning software
4	Real Time Interaction between Human and functional virtual production system or machine	X	+ Haptic interaction	+ in spec. planning software
5	Usage of planning tools from all state of the art application fields	X		+ without exchange formats
6	Flexibility - Easy Exchange of elements and user test setup	X		
7	Easy Use and Maintainability of Test environment	X		+ less expert knowledge