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Virtual Test Scenarios for Human-Centered Design with Virtual Measurement Systems

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Summary:
The involvement of human workers is an essential part of the design of production systems. In this context, test scenarios in Virtual Reality are increasingly used to verify the fulfillment of requirements. This paper proposes a procedure for generating virtual test scenarios. The objective is to support human-centered design by means of virtual measurement systems. The procedure involves three steps: selecting relevant human factors in requirements, modeling the virtual test scenario, and carrying out the verification study. The goal is to advance the significance of testing outputs.

Keywords: virtual reality, virtual measurement systems, virtual test scenario, human-centered design

Introduction

One focus in the context of production systems in recent years has been on human-centered design. With the early consideration of human needs, the production system can be suitably designed. For this purpose, human factors requirements have to be met and verified during the design process. Verification is essential in established design methodologies that can be adopted for production systems such as the V-model of VDI/VDE 2206 [1]. Based on findings of verification activities, design change processes can be initiated. Virtual reality enables the assurance of production planning and control at design time. Due to immersion, the human-technology interaction in particular can be tested within the Virtual Reality. Based on human factors requirements, suitable test scenarios with measurement systems have to be defined. A virtual test scenario includes the virtual shape of the system under consideration, the definition of the environment and the definition of the data collection technique and its evaluation. Established measurement methods are only suitable to a limited extent in Virtual Reality and are time-consuming due to manual measurement. The aim of this paper is to develop a procedure for generating virtual test scenarios for human-centered design with virtual measurement systems that do not require time-consuming manual measurement.

Human Factors in Virtual Reality

Within future production systems of the future, the employee continues to be a decisive factor. Important design features are workplace design, work organization and time planning. The design features can either facilitate or hinder human work. Human factors design is concerned with the integration of human ergonomics, characteristics and capabilities into design problems. The aim is to improve productivity, safety and at the same time consider well-being of employees. Crucial within human factors design is the continuous verification of the system elements with regard to human factors requirements. Results from Lanzotti et al. [2] show that virtual reality offers an interactive possibility to verify human factors requirements. Buchholz et al. [3] develop a first initial testbench for human-centered requirements with virtual tools. According to Aromaa and Väänänen [4], the key factors concern modelling of the system (fidelity, virtuality, manipulation possibilities, etc.), modelling of the environment as well as data collection and analysis techniques. Studies [5] show a variety of applications and forms of these three factors in the verification of human design in virtual reality.

Virtual test scenarios for human-centered design with virtual measurement system

The procedure developed for generating test scenarios for human-centered design with virtual measurement systems basically consists of three steps (see Fig. 1). In the first step, specific human factors requirements are selected. Based on the traceability in the system model, associated functions, logical elements and system elements as well as behavioural properties are identified. In the second step, the virtual test scenario is modelled. Based on the results of step 1, the modelling of the system is first determined. System elements are realized with defined behaviour in Virtual Reality.

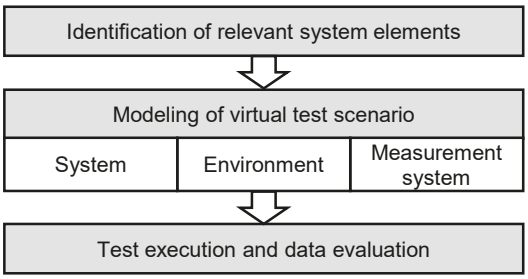

Fig. 1. Procedure for generating test scenarios

Furthermore, the environment is modelled. Depending on the requirements and the relevant human factors aspects (perceptual, mental, physical and psychosocial), the environment is modelled in a specific level of detail. For example, for perception-related aspect, the environment may have to be modelled in greater detail than for an ergonomic test. Finally, the virtual measurement system is selected. This is used for data collection. The selection is again based on human factors aspects. In the third step, the verification study is carried out. The test person is brought into the virtual environment with the help of VR goggles and carries out the defined test scenario with or without guidance.

Case example

Case example is the design of a manual assembly workstation in a flow assembly for linear actuators. For this purpose, requirements for the system were collected with stakeholders such as occupational safety. Tab. 1 shows an excerpt of the ergonomic requirements as a subset of human factors requirements for the workplace. Within a virtual test scenario, it is now to be verified whether the current design of the assembly workstation satisfies DIN ISO 14738.

Tab. 1: Excerpt of the ergonomic requirements of the DIN ISO 14738

#	Element	Requirement	Value
7.1	assembly table	Workspace depth	415 [mm]
7.7	assembly table	Viewpoint	30 [°]
…	…	…	…

Based on the system model of the assembly workstation, the assembly table with necessary accessories such as tools and containers are required. The workplace must have real physical properties. The tools are the only elements that can be manipulated in their position. As the requirement refers to ergonomic physical human factors aspects, the environment does not need to be explicitly modelled. The sensors on the HMD and controller as well as the use of "colliders" are selected as virtual measurement systems. Fig. 2 shows an excerpt from the implementation of the virtual test scenario in the VR-Software developed with Unity3D.

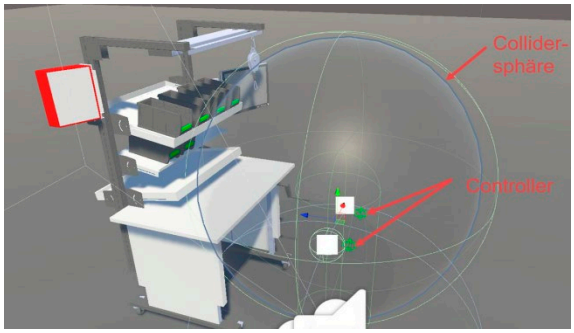

Fig. 2. Virtual test scenario with virtual measurement systems

The virtual measuring system measures the movements of the employees during the execution of a test task. These are, for example, the duration of a movement and directions of movements. Critical movements, such as permissible movement space, are output via a console and can be transferred to a design review report [6].

Summary

The paper at hand shows a systematic procedure for generating virtual test scenarios based on requirements. Besides the generation and modelling of the virtual environment, the appropriate selection of virtual measurement systems is a crucial step. This is facilitated by a systematic pre-selection and can be easily implemented. The procedure was demonstrated using the example of the design of an assembly workstation. In future studies, the process will be further automated to generate simple derivations of virtual test scenarios without manual effort.

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