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Virtual and augmented reality support for discrete manufacturing system simulation

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Abstract

Nowadays companies operate in a difficult environment: the dynamics of innovations increase and product life cycles become shorter. Furthermore products and the corresponding manufacturing processes get more and more complex. Therefore, companies need new methods for the planning of manufacturing systems. One promising approach in this context is *digital factory/virtual production*—the modeling and analysis of computer models of the planned factory with the objective to reduce time and costs. For the modeling and analysis various simulation methods and programs have been developed. They are a highly valuable support for planning and visualizing the manufacturing system. But there is one major disadvantage: only experienced and long trained experts are able to operate with these programs. The graphical user interface is very complex and not intuitive to use. This results in an extensive and error-prone modeling of complex simulation models and a time-consuming interpretation of the simulation results.

To overcome these weak points, intuitive and understandable man–machine interfaces like augmented and virtual reality can be used. This paper describes the architecture of a system which uses the technologies of augmented and virtual reality to support the planning process of complex manufacturing systems. The proposed system assists the user in modeling, the validation of the simulation model, and the subsequent optimization of the production system. A general application of the VR- and AR-technologies and of the simulation is realized by the development of appropriate linking and integration

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mechanisms. For the visualization of the arising 3D-data within the VR- and AR-environments, a dedicated 3D-rendering library is used.

Keywords: Virtual reality; Augmented reality; Production planning; Simulation

1. Introduction

A constant competition of businesses demands short product cycles and fast changes of products: the dynamics of innovations increase; the product life cycles become shorter; at the same time, the products become more complex; the keen competition forces companies to respond to changes of the market. It is important, that either the production processes are adjusted as quickly as possible to new circumstances or new production processes are planned in the way that they yield the required results straightaway [1,37].

The keywords *digital factory* and *virtual production* refer to a new approach, how to cope with the above mentioned challenges [2]. In this context, the discrete simulation of the behavior of production facilities is of particular importance. At first, the development of a simulation model is essential. Therefore, the considered system is analyzed and a computer-internal model is developed. This includes the modeling of functions, processes, behavior patterns or rules, which are to reflect the actual interrelations of effects in a business in this model [3]. The modeled aspects are linked together in the way that all functions of the model represent a whole. For various problems, extensive models with a complex behavior are required. However, an increasing size and complexity of the simulation model lead to more work for modeling, a higher error-rate and runtime, and to more work for interpretation when analyzing the results. Errors in modeling result in misinterpretation and false results in a simulation.

In this context, the design of the user interface is very important [4]. For the usual, little intuitive WIMP-Interface (Windows, Icons, Mouse, Pointer) highly trained users are required so that the development of complex simulation models involves a lot of time. The simulation results are presented in the form of spread sheets and of two-dimensional, abstract illustrations of the production system. This seems to be adequate for simulation experts, but it is not acceptable for a multidisciplinary planning team consisting of people from diverse departments of a company. Therefore, the development of a simulation tool having more than an intuitively understandable user interface is required.

2. State-of-the-art

2.1. VR-technology

The rendering of virtual three-dimensional worlds is made by image computations of abstract, mathematical 3D-models (e.g. polygons) describing a virtual world [42]. In case of real-time-rendering images are computed with at least 20 images per second in order to facilitate navigation in a virtual scene. 3D-rendering systems are programmed via an abstracting interface in the form of a low-level graphic library like *OpenGL* or *Direct3D* and they have specific graphic hardware for a fast execution of arithmetic operations. High-level libraries (e.g. *OpenInventor*, *Performer*, *OpenSG*, *OpenScene-Graph)* support comfortably the programmer with a structured view on the 3D-model data by means of a hierarchically built scene graph when organizing, constructing, handling, and interacting with the virtual 3D-world. PCs with graphic hardware display scenes of up to several hundreds of thousands polygons in real-time. More than one million polygons are often required (e.g. by using 3D-CAD-models). The virtual scenes of manufacturing plants are so complex that they cannot be displayed in real-time on a single PC without the application of specific techniques [5]. The reduction of complexity (approximation) [6–8] and the computation of hidden objects (visibility culling) [9,10] are two main approaches for real-time rendering.

In this context, the development of games and the research of computer graphics have been successful, though they are also limited concerning the structure of the scene (topology), the dynamic behavior, or the