Combining Virtual Reality and Assembly Simulation for Production Planning and Worker Qualification

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Abstract
Virtual reality and assembly simulation are both technologies which are established in their respective application fields. Using simulation for assembly and factory planning is well-known and its usage is further encouraged by the visions of the digital factory. Virtual reality on the other hand is an established technology for performing design reviews (esp. in the automotive industry) and is a rather product oriented technology. In the areas of production planning the usage of virtual reality is not yet very wide-spread.
The approach described in this article combines both approaches, i.e. assembly simulation and virtual reality, to create fully-interactive and immersive 3D visualisations of assembly lines and factories. In such virtual environments users can experience and interact with the virtual representation of their factory. Usage scenarios include the design phase of the factory as well as the operation phase. Targeted end users include classical factory planners, decision makers and even the individual assembly worker, who can train assembly tasks in a virtual environment.

Keywords
Virtual Reality, Assembly, Simulation, Qualification, Planning

1 INTRODUCTION

Virtual reality and assembly simulation are both technologies which are established in their respective application fields and which have gained importance with the objectives put forward by the vision of the digital factory. Virtual reality is most commonly used for design reviews and is therefore often considered as a rather product oriented technology [1]. In the areas of production planning the usage of virtual reality is not yet very wide-spread. Some solutions exist for visualizing factory layouts in the planning phase. However, these solutions are often limited to static layout planning.

The combination of both approaches, i.e. assembly simulation and virtual reality, allows the creation of fully-interactive and immersive 3D visualisations of assembly lines and factories. In these virtual-interactive environments users can experience their simulation model, they can walk through their virtual factories, they can visually inspect the different stations, interactively analyze bottlenecks, etc.

2 OBJECTIVES

The overall objective of the solutions described in this article is to provide a virtual-interactive environment which supports the entire life cycle of a factory. The term “virtual-interactive” denotes the capability of the environment to display and navigate through a virtual 3D-model and to allow a wide range of user interactions with this model.

Towards this objective the environment must support tasks like factory design, production program planning, process optimization, and worker qualification [2]. The applicability must not be limited to the design and planning phases of a factory, but also has to include the operation phase.

Therefore the environment has to offer advanced planning, simulation and visualization capabilities under a unified user interface.

Furthermore, an important requirement for such a virtual environment is its interactivity which has to be supported in different ways [3]:

1) The user must be able to interact intuitively with the virtual factory depicted in the virtual environment. He has to be able to obtain additional information by interacting with the visualized components, e.g., by selecting a station and requesting a detailed use statistics.
2) The user shall be able to interactively influence the *simulation run* from the virtual environment by changing routings, processing times, worker allocations, etc. This provides the capability for the user to experiment with the model in an immersive environment as if he is standing in a real factory.
3) The user must be able to interactively modify the *simulation model*. This case is partially similar to the previous alternative with the difference that the users actions indeed change the simulation model of the simulator permanently.
4) The user can be inserted into the simulation, e.g., take over tasks of workers which are normally part of the simulation. This can be done for training purposes, e.g., to show workers which effects certain actions will have.

3 IMPLEMENTATION

The technical basis for enabling such virtual environments can be achieved by coupling one or more simulation systems with a virtual reality system. This has the advantage that existing and reliable tools can be used in their respective field of expertise. It is not useful to implement a single tool which would fulfil all objectives stated earlier. Instead, we suggest to perform dynamic online coupling of these tools at runtime.

The technical solution for the coupling has to define the interfaces between the systems. For the runtime communication well known standards like HLA [4] or simple network interfaces like TCP/IP exist. Using standards like HLA has the advantage that issues like synchronization between the VR and the simulation are automatically been taken care of .

For the exchange of models between the systems a different kind of interface is needed. This type of interface must be able to translate model structures between VR and simulation, e.g., to generate a simulation model from the VR model, or to import the layout of the simulation into the VR environment.

In various projects at the Fraunhofer IFF different solutions for both types of interfaces have been implemented and tested.

4 PILOT PROJECTS

4.1 Combination of VR and Simulation for Foundry Planning

In a pilot project conducted with Rautenbach Guss Wernigerode GmbH a toolset has been developed for the factory planner of foundries. This toolset is based on the VR environment of the Fraunhofer IFF [5]. The toolset allows the creation of interactive 3D models for designing and redesigning foundries. The models can be used for evaluation and realistic presentation of different alternatives for producing future orders.

Within the project efficient methods and tools for producing foundry-specific models have been implemented. The virtual planning environment provides users with an extensive library of typical foundry components, e.g., for core production, melting operations, casting, cutting, and product completion. With these components interactive 3D-models of the foundry can be created efficiently (Figure 1).

In the frame of this project two interfaces between virtual environment and simulation systems have been implemented:

1) Export interface for generating a simulation model from the virtual reality model
2) Import interface for visualizing simulation results (statistics, trace file) in the virtual environment.

The simulator eM-Plant was used in this pilot project as the reference simulator. The export interface of the virtual environment produces a simulator neutral format from which a script in the simulator can generate the actual simulation model.

The import interface of the virtual environment can read standard trace files as they are produced by eM-Plant and visualize the simulation run (Figure 2). Other trace formats can be converted into this format easily.

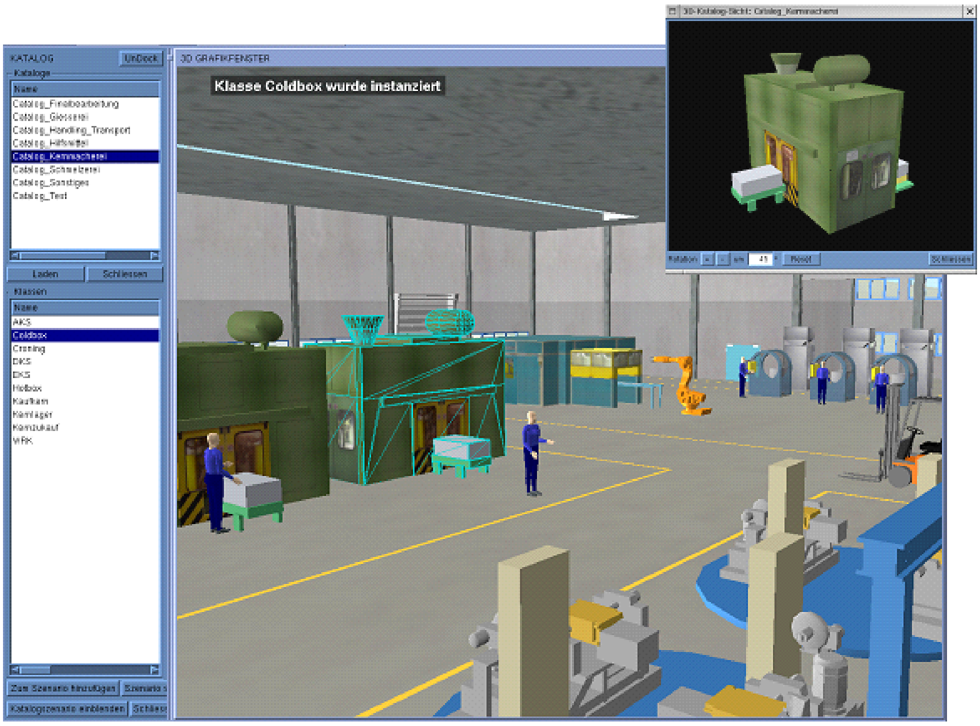

Figure 1: Easy model creation by using predefined library components

With these two interfaces a neutral format between virtual environment and simulator exists. This allows the easy exchange of the simulator according to customer preferences.

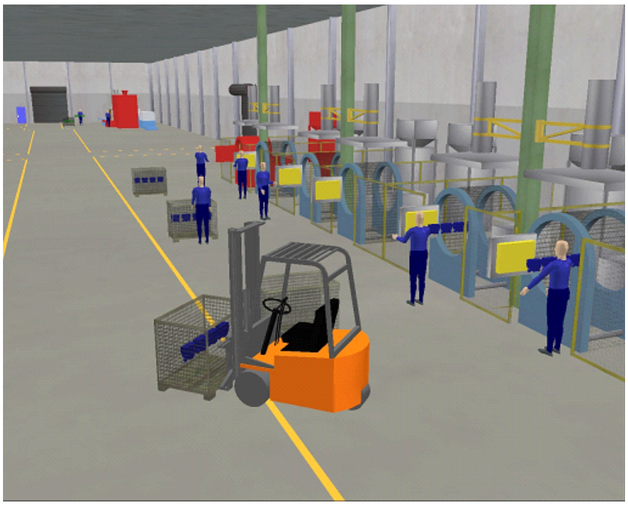

Figure 2: Visualization of a cylinder head production

4.2 Combination of VR and Simulation for Assembler Training

With the objective of training assembly workers in a virtual environment different levels of training depending on the interactivity, guidance and realism required, can be distinguished.

1) Assembly Visualization

In this alternative the sequence of assembly steps is visualized in a virtual environment. User interactivity is limited to viewing each procedure step, jumping backward and forward, inspecting and querying information about assembly parts, and choosing view points. He has the possibility to explore the whole virtual scene with the objective of investigating functional dependencies.

Figure 3 shows an example for visualizing the assembly of a power generator, a project conducted with the AEM GmbH.

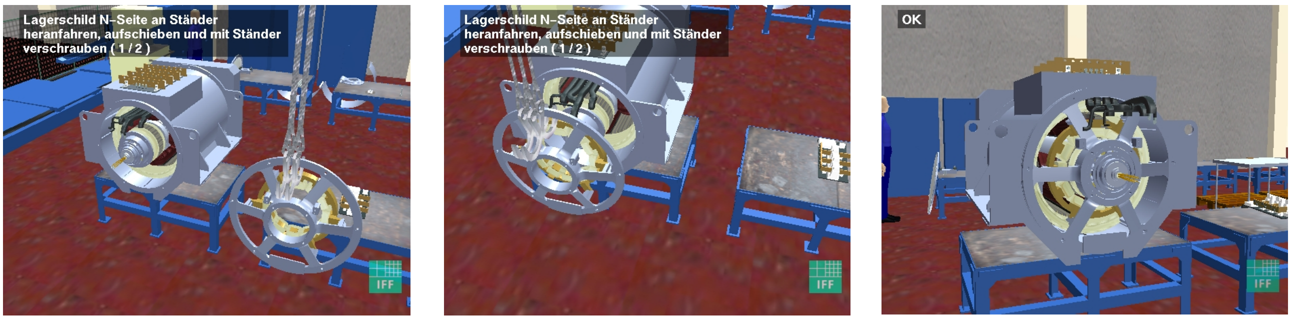

Figure 3: Assembly visualization

2) Assembly Procedure Training

This alternative is similar to 1), but has the added feature that the trainee has to perform the assembly tasks by himself.

He has to memorize the right sequence of steps and performs the assembly in the virtual environment. The tutoring system will indicate the potential mistakes that have been made and is giving hints if desired. Even a rating of the assembly performance is possible.

3) Integrated Virtual Assembler Training

This alternative integrates the procedural assembly training with a dynamic, simulated environment of the virtual factory. The assembly line of the factory is simulated by an assembly simulation in a commercial simulator. The simulator is connected on-line with the virtual environment. Both systems are synchronized [6]. The trainee can take over any assembler in the virtual environment and perform its assigned assembly tasks. Performance of the assembler (e.g. durations for task completion) is feedback to the simulation where it is taken into account accordingly.

A pilot project was conducted with a producer of commercial vehicles. Its objective was aimed at the long-term vision to develop a Virtual Reality training environment for production assemblers. The pilot project combined an existing capability to perform detailed assembly simulations with their interactive visualization in a virtual environment.

The ability to virtually create an assembly line very early in the design/development process allows management and personnel to collaborate on the evaluation of manufacturing, ergonomic, safety and part flow issues before the design is finalized in order to discover potential problems before they become costly to fix. In this way it is possible to qualify workers at the earliest by using the virtual assembly line before the real one is available.

5 CONCLUSIONS

The overall objective of the solutions described in this article is to provide a virtual-interactive environment which supports the entire life cycle of a factory.

This includes the usage of VR as a command and control tool for factory design and factory operation. The virtual world can act as the integration platform for different simulation models (e.g. OEM supplier models developed in different simulation tools) [7]. In the design phase of the factory the processes of the planned factory can be tested and optimized within the VR world. This very world can be enhanced by didactical knowledge to qualify workers for assembly procedures.

In the operation phase of the factory the VR world can act as the virtual representation of the real factory. Based on on-line simulation concepts [8] and a connection to the shop-floor systems the state of the VR world (and the connected simulations) can reflect the state of the real factory. In case of emergencies (e.g. machine failure) the factory operator can plan and test different plans of action (fast-forward simulation) and select the best option.

In summary, the issue of combining simulation and virtual reality into truly interactive and immersive environments is the next logical step in the development of visual 3D simulations and is a logical consequence derived from the requirements of the digital factory. The wide application areas include the virtual-interactive planning and design of new factories, the support for operating a factory, the worker qualification and many more.

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