COMPONENTS FOR THE ACTIVE SUPPORT OF THE ANALYSIS OF MATERIAL FLOW SIMULATIONS IN A VIRTUAL ENVIRONMENT

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ABSTRACT

Simulation and visualization are well-known methods for the understanding and analyzing of manufacturing processes. In visualizations of manufacturing processes the viewer can move around freely and unguided. Thus knowledge and conclusions are only acquired on a random base. This article outlines a system and methods that support the viewer to keep an eye on noticeable/significant processes/points in the material flow simulation and to optimize these processes.
This article describes the development of a tool, which enables the viewer of a simulation to interactively improve significant production processes. The viewer moves in a virtual 3D-environment (walkthrough system) and can acquire automatically calculated indications for significant processes. At the same time the simulation should simulate significant objects in a more detailed way. If the viewer is interested in a significant process, he is automatically guided to the relevant place where he can examine the critical situation by interference in the simulation. Since the critical moment is in the past and is thus already missed by the viewer, the viewer is able to rollback the simulation to a time before he entered the simulation.

OBJECTIVES

Visualizations of manufacturing processes typically allows the viewer to move around freely and unguided. This leads to random process mostly based on the experience of the viewer to acquire knowledge and conclusions. A tool is required which enables the viewer of a simulation to interactively detect and improve significant production processes. The viewer is able to move in a virtual environment and acquire (semi-) automatically calculated indications for significant processes. If the viewer is interested in a significant process, he is automatically guided to the relevant place where he can examine the critical situation by interaction with the simulation. Since the critical moment is in the past and therefore already missed by the viewer, the viewer is able to rollback the simulation to a time before the significant process occured.

Such a system has to possess the following characteristics: there have to be methods for the automatic detection and rating of significant points and processes in a simulation. Important and unimportant points are differentiated in a pre-filtering process in order to facilitate the choice of huge numbers of significant points. There have to be interaction techniques with the user. Methods to guide the viewer in a virtual environment have to be available. Suitable algorithms for the visualization of points with differently high significance in a room must support the visualization in a walkthrough-system. Since the attention of the viewer is drawn to significant points, both the position of the viewer and the significance of the object serve as indicator for a high detailing of the simulation. A rollback in the simulation as well as in the visualization has to be made available for the viewer. Suitable algorithms for the visualization of points with differently high significance have to take into account the special characteristics of simulation environments in a walkthrough-system.

The virtual scene or its 3D-models of a dynamic simulation environment are generally too complex to visualize them in real-time (Möller and Haines 1999). Typically approximation methods are applied in order to visualize them with a low loss of quality in real-time in a walkthrough-system and to enable an easy navigation for the viewer of the virtual scene. Two basic approaches are the complexity reduction (approximation) (Luebke 1997 and Garland 1999) and the calculation of hidden objects (Visibility-Culling) (Durand 2000). Exact information about the priorities in the virtual scene is made available by the specific simulation requirements concerning the significant points. The simulation knows that the virtual objects at significant points are very important. These significant points can be at any place in the scene. This knowledge enables the approximation algorithms to use a high rendering quality or a high rendering power for the simulation-models of significant points and accordingly to neglect the other parts of the virtual scene. Such approximation algorithms and data structures use the

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specific characteristics of virtual scenes in simulation environments and enable a higher rendering quality and rendering power than a system in which no assumptions of the scenes can be made.

Objects with a high significance have a big influence on the simulation. Thus, a more detailed view is reasonable out of the perspective of the user as well as of the simulation. Thus methods are developed which carry out the simulation of these objects in a more detailed way (like Dangelmaier, Fahrentholz and Mueck 2002) and therefore also more accurate.

STATE OF THE ART

Today material flow simulations offer installed 3D-modules (Klingstam and Gullander 1999). Examples are simulation tools such as QUEST by Deneb, Taylor ED by Enterprise Dynamics (Nordgren 2001), or eM-plant by Technomatix with integrated, virtual environments. These systems offer only conditionally the possibility to dynamically influence and analyze a scene. Furthermore they take place on the computer on which the simulation runs. The simulation has to share the available computing time with the visualization. This decreases the speed of execution of the simulation and it also reduces the rendering quality of the visualization. It is especially difficult for the visualization to forecast the fluctuations of the required computing time of a simulation. Often a constantly high refresh rate is not possible with many polygons.

These systems can also analyze material flow simulations. An active support does not take place. If the viewer moves in the relevant system, he cannot experience critical processes which take place in his back and are not visible for him. User guidance to significant points is not known. The locating of critical objects is thus left to the experience of the viewer or to chance.

SYSTEM DESIGN OF A 3D-SIMULATION ENVIRONMENT

The draft at the beginning results in many requirements the system has to meet. There are requirements for the modeling and simulation as well as for the visualization and for the rendering methods in the 3D-system (walk-through-system).

Experimentation platform

There has to be a solid experimentation platform with allows the user to look at the simulation in a virtual environment and also to experiment interactively. For this purpose a simulator has to be chosen and connected online to a visualization component.

Thereby a number of interactions for the modification/parameterization of the model are necessary for the visualization. The modifications/parameterizations carried out in the visualization have to be processed correctly in the simulator. Especially the rollback demands basic methods of the simulator.

Identification, rating, and visualization of significant objects

Not all processes in a simulation are equally important for the user. He wants to know where irregularities and problems occur (e.g. a blocking machine or empty stock). Such processes are significant for problems in the manufacturing. In the here-described system significant simulation processes should be automatically identified and explained to the user.

For this purpose significant points have to be identified. Suitable methods for the support of the modeler to set up sensors for significant processes have to be integrated. Beside the semi-automated modeler supportet sensor approach to identify significant processes a fully automated method is under development.

A proper rating of the significance of the objects has to be made. If an error , which puts many objects in the condition “significant”, occurs at one point of time, then only the actuator of the error should to be indicated to the user. For this purpose, the number of significant points has to be filtered. If the user has already solved the problem or prioritized a spot, then the significant incidences at this object are to be reported preferentially.

The number of significant points for the user is put in the foreground by an adjusted visualization. At the same time the visual view of other objects in the virtual scene, which are not significant, has to be reduced. Therefore appropriate visualization methods are to be applied (e.g. semitransparent objects).

Guidance to significant points

In today’s approaches there is no real guidance of the user. Thus the identification of critical processes and connections is highly dependent on the experience and the intuition of the user. It takes places in disorder and rather coincidentally. In our system the direct guidance allows the user to acquire more efficient, structured and thus faster the relevant information and go to places that have a strong influence on the simulation (see figure 1).

The user should have the option to be guided o „significant“ points and to change or at least parameterize the simulation model anew. Therefore suitable interaction techniques are developed.

If the user makes use of the option to be guided to a significant point, he is directly transported to this point or the route from his current position to this point has to be determined. In order to give the viewer the impression that he moves in a real hall, he moves along usual traffic route. Machines and walls can cause an unsatisfied optical view and disorientation by occlusion. If visible objects lie between the significant object and the position of the viewer, the viewer has to go round these objects. For this purpose traffic routes have to be modeled and a suitable route has to be automatically determined in the model (see figure 2). The user should be guided by markings or guided automatically. Along his way both the simulation and the visualization should to take place highly detailed.

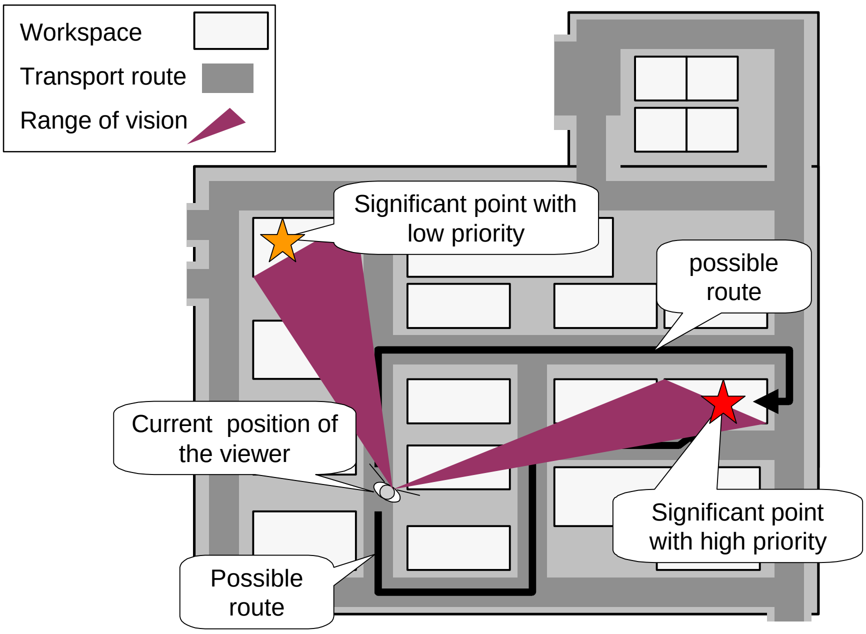

Figure 1: Automatic calculation of the route

Changing the Resolution of the Simulation

Simulations in a high resolution require a long execution time. In large models with a high resolution this can lead to an execution, which is slower than in real time. The use of parallel computing systems provides more comput-ing power and thus permits an acceleration of the computa-tion. The problem is thereby only shifted to an-other level.

In order to give the viewer the feeling of a high detailing at all places of the simulation, a method was developed whereby only the part of the simulation, where the viewer stands, is carried out highly detailed (Dangelmaier, Fahrentholz and Mueck 2002). Places that are farther away from the viewer are simulated on a rougher level. If the viewer changes his position, a higher detailing in the simulation is automatically updated. Thus the viewer gets the impression of a continuous high detailing without a high computing power. Bigger simulations can be experienced. But an inexact calculation of those parts, which are not located within the visual focus of the user has to be accepted. This leads to inexact simulation results.

Since both the attention of the viewer to significant objects, and the influence of significant processes on the simulation are increased, the level of detailing of these objects should be determined by the viewer position and the significance of the objects. This has to be integrated in the experimentation platform.

Multi-Point-Approximations for virtual scenes with significant points

In the following the system requirements for the walkthrough-system in the area data structure and real-time-algorithms are explained, which are necessary for the visualization in a virtual scene:

- Real-time navigation: a walkthrough-system is needed which allows for a free navigation in the scene, i.e. the rendering-algorithms have to be able to calculate pictures of the virtual scene with at least 10-20fps (frames per second).
- Dynamics: our scene must be dynamic, i.e. objects can be inserted or deleted by the simulator or the user at any time.
- Kinematics: typically the scene has high kinematics. Many objects (in an extreme case all objects) move with high speed to any places in the virtual scene.

- Complexity of the scene: the models of the virtual scene result from exported models of CAD-systems. Typically they have a high complexity of polygons. Thus the virtual scene consists of several gigabytes of scene data, which does not fit as a whole in the main terminal or cannot be visualized in real-time without application of expert methods.

The last requirement for the walkthrough-system makes the solution for the other three requirements more difficult. The virtual scene can only be modeled by means of 3D-approximation methods. The workflow can be organized efficiently by automatic approximation methods, which do not demand an after-treatment of 3D-models. However, the most important questions concern the nature of the required approximation.

The detailing and the approximation quality of the objects in the virtual scene are contrary to the traditional approaches because they are not dependent on the position and the direction of view of the user. Especially positions with significant processes and the way to these positions serve as a better indicator for a high detailing than the simple distance or the projected size of the object. The significant points in the virtual scene cause a deliberate imbalance of the qualitative visualization.

Multi-Point-Approximations are methods which improve the rendering quality of objects in the range of significant points independent of their distance and which reduce the rendering quality of non-significant points (see figure 2). Thus a limited rendering-time is purposefully used for the parts of the scene, which are interesting for the simulation because the user is interested in these pares. There is no "waste" of rendering-time by a high weighting of close, non-significant objects as it is the case in traditional methods which do not allow to make assumptions for the design of the scene. Approximation methods and rendering-algorithms are required which allow for the purposeful weighting of different independent points of the virtual scene.

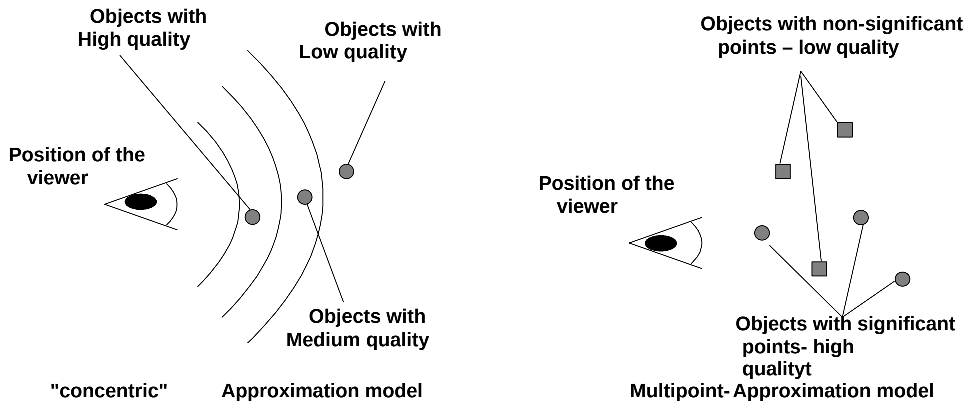

Figure 2: Comparison "concentric approximation model" and Multi-Point-approximation model

Thus the algorithmic problems are to a great extent influenced by simulation requirements. Also requirements for the "visualization + simulation" have to be taken into account. A simulation with randomly arranged, significant points which wants to call the viewer's attention to these points has to use visualization methods in order to visually emphasize these points. For this purpose, methods such as the dynamic use of "transparency" or the "lowering of non-significant objects" have to be applied (see figure 3 and figure 4). In doing so, there is a change of visibility behavior of the static parts of the scene in a relatively short time interval. This results again in the requirement for the approximation method and visibility-culling-algorithms of the rendering of the scene to consider the dynamic changes of the topology.

Concluding, the simulation involves many specific, methodical requirements for the data structures and algorithms for the rendering of the virtual scene, which are not all covered by traditional methods in the approximation and visibility-culling field.

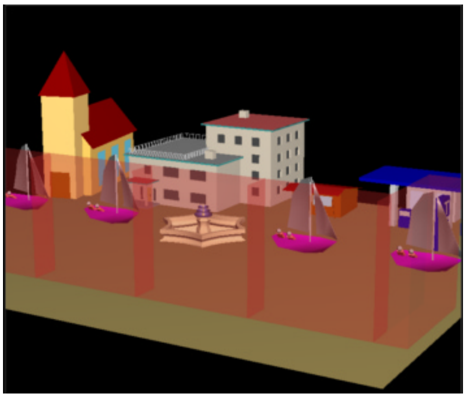

Figure 3: In this setting the fountains and boats are „significant“ points. The wall in the front is transparent.

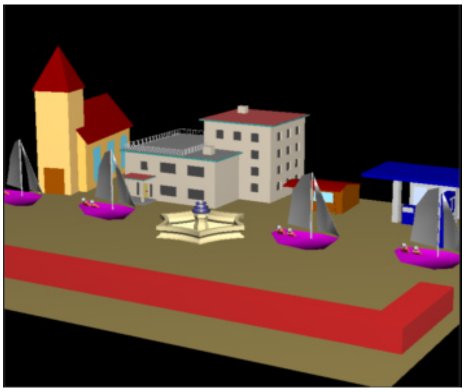

Figure 4: Like figure 3, however instead of transparency only the outline of all objects (here the wall), which obstruct the view on „significant“ points, is drawn.

CONCLUSION

Today there is not yet an active support for the analysis of material flows in simulations. This article outlines a system, which determines and visualizes objects to the viewer that are significant for the simulation. Both a more detailed simulation and a visualization of these objects take place. Thus, the user is directed to the most important objects of the simulation instead of walking aimless through the virtual environment. These objects are simulated and visualized more detailed. The viewer can concentrate his attention and his interactive optimization on objects, which have a high influence. The analysis and interactive optimization can take place faster and more efficient. The system described in this article is currently under development and should demonstrate the benefits and the feasibility.

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