

SIMULATION OF COMMISSIONING IN WAREHOUSE

SIMULACIJA KOMISIONIRANJA V SKLADIŠČU

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Abstract

To understand the dynamic behaviour of the systems and verify implemented designs or processes in a particular time frame the use of simulation studies is necessary. Although the amount of time and data used to produce such studies are substantial, the 3D representation of the system produces a fuller understanding of system behaviour. This paper describes the use of 3D animation to visualize workflows in a warehouse using standard techniques within Web browsers or standalone applications. The success of a 3D simulation depends on object behaviour and the level of interaction. Based on an X3D node concept, object-oriented features, and an event-driven approach, the application is well-suited to the virtual environment. XML is used as the interface definition of nodes and the parameters of their behaviour characteristics. Automated nodes and code generation of a dynamic XML Schema simplify the implementation. The study of a specific application enables us to highlight the possibilities of the X3D language to model, to visualize, and to change interactive parameters for actions in the warehouse-commissioning process. Key features of X3D are revealed, and new approaches are proposed to achieve a better realistic behaviour inside the virtual warehouse. The information from simulations in the virtual warehouse is directly usable to optimize performance and further operational planning in the warehouse.

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Povzetek

Za razumevanje obnašanja dinamičnih sistemov in verificiranje kreiranih modelov in procesov v časovnih okvirjih je nujna izvedba simulacijskih študij. Čeprav je količina podatkov in časa potrebnega za pripravo simulacij obsežna, 3D simulacije omogočajo bistveno boljši vpogled in razumevanje delovanja sistema. Članek opisuje uporabo 3D animacij za prikaz delovnega toka v skladišču z uporabo standardnih animacijskih tehnik spletnih brskalnikov ali samostojnih aplikacij. Kakovost 3D aplikacij na spletu je odvisna od obnašanja objekta in stopnjo interakcije, ki jo omogoča. Koncept standarda X3D z vozlišči in objektno usmerjenimi funkcijskimi lastnostmi je dobra osnova za simulacijo v virtualnem okolju. Za vmesnik uporabljamo XML in sistem zapisovanja karakteristik vozlišč s parametri pri čemer uporaba dinamična XML Shema poenostavlja izvajanje kode za avtomatsko generiranje vozlišč in njihovega obnašanja. Raziskava in kreiranje specializirane aplikacije nam omogoča prikazati prednosti X3D modela, za vizualizacijo in pripravo interaktivnih parametrov za spreminjanje funkcij v skladišču med komisioniranjem. Izpostavljene so glavne značilnosti in predlagan nov pristop za doseganje višjega nivoja realističnosti prikaza delovnega toka v virtualnem skladišču. Z simulacijami pridobljene informacije je mogoče neposredno uporabiti za optimiranje procesov v skladišču.

1 INTRODUCTION

The information technology (IT) evolution is currently dominated by the Internet, whose widespread use of technologies and the development of proprietary Web-based 3D formats has resulted in an increased number of 3D-enhanced Web applications. Global and intra-corporate access, platform independence, maintenance minimization, reusability, and interoperability are among the significant aspects and requirements that present challenges for all fields of IT application. The 3D technologies and their availability on consumer platforms are continually growing.

This paper describes the architecture of a new tool addressing the visualization of activities in a warehouse adopting the framework tools developed for sharing of virtual prototypes over the Web with standard programming tools, [1]. The framework was further developed for integration of CAD and desktop VR with kinematic mechanism simulation, [2], offering wide possibilities of variation via a configuration file in XML format.

The evaluation of activities in a warehouse are time dependent and results in time frame modifications. Consequently, solutions are changed, affecting many parameters. The developed model enables cooperation of a broad set of participants in the process, irrespective of tools used for modelling. This tool gives the opportunity for interactive modifications in configuration from a prescribed set of parameters, including their functionality description. The desktop VR system is used inside a Web browser or as a standalone application visualized with X3D using XML as the interface and configuration data carrier.

In order to share the product or process solutions, a great deal of manual work to transfer the simulation into the virtual environment as a virtual prototype is required. This paper describes the starting research to adopt developed solution for VR assembly and kinematics of models for warehouse activities using the same principle but different parameters, as the goals of the research are different. The architecture of the application addressing the warehouse VP uses standard Web programming tools. The proposed approach enables the cooperation of a broad set of participants in the process, irrespective of tools used for modelling the product.

2 BACKGROUND

3D visualization is becoming increasingly popular for discrete event simulation. However, the 3D visualization of many of the commercial off-the-shelf simulation packages does not reflect the state of the art of the rapidly developing area of computer graphics.

There are several purposes for visualization, which can be categorized as validation, analysis, and marketing, [3]. Displaying graphical images of the dynamic behaviour of a model during execution enables the user to discover errors visually. Following the animation of the model as it is running and comparing it with real life operation helps the user to identify discrepancies between the model and the system. Analysis refers to the process of gathering information and drawing conclusions from the simulation. Where statistics can show that a production line is inefficient, visualization can be used to locate the bottlenecks. The third term, marketing, refers to increasing the confidence of people in the provided solution. This means both convincing companies to buy the software and convincing non-engineers of the validity of the result.

Warehouse simulation is the computer-based modelling of a real warehousing system. Simulation enables an organization to analyse and experiment with its warehousing process in a virtual setting, reducing the time and cost requirements associated with physical testing. Storage, docks, conveyors, forklifts and even personnel can quickly be introduced and adjusted within the simulation model, allowing companies the opportunity to determine how to fully utilize their equipment and maximize efficiency. The need for efficiency in industry has never been greater, with personnel, fuel, transportation and material costs continuing to rise. Simulation provides a means of putting a warehouse to the test in a risk-free environment without disturbing the existing warehouse system. It also enables users to determine minimum actual costs without sacrificing the required output.

Regarding object geometry, a variety of excellent modelling and authoring tools and format converters already exist. There are many interesting proprietary Web technologies for building rich 3D content. However, most of them are tailored for specific application domains and limited in producing dynamic 3D scenes. Necessary behaviour extensions are not easily accomplished. Script languages are essentially the only way to achieve applications with complex behaviour. VRML as the standard for 3D graphics on the Web and its successor X3D, [4], offer greater flexibility with inbuilt behaviour related nodes, script nodes, and extensibility mechanisms. X3D is an ISO-ratified open standards file format with run-time architecture to represent and communicate 3D scenes and objects using XML. It provides a system for the storage, retrieval, and playback of real-time graphics content embedded in applications, all within an open architecture. X3D has a rich set of componentized features that can be tailored for use in engineering visualization, training, and simulation.

XML is a public, neutral format that can be used in Web applications with the ability to separate the content and the form of data. XML is an attractive choice as the representation language because the parsers are easy to obtain, and it two specific characteristics : being well suited for data exchange over the Web, and for the creation of user interfaces in various formats. An XML file is a hierarchically structured document in which the objects are denoted by tags containing plain data or additional objects or combinations of both. Attributes are name-value pairs that occur inside tags after the object name. The properly nested objects define the hierarchical structure and may contain references. With a DOM parser, it is possible to read the input file in XML, check formatting and semantic validity, as well as build and present a complex hierarchical object structure with few lines of code.

VP techniques require significant computing power to provide basic requirements, as viewing and interactions with real-time response. The problems of global cooperation over the Web are reduced with more or less specialized viewers surveyed in [5]. In order to integrate the virtual world, heterogeneous data sources should be composed. At the data level, this requires converting and processing different data formats. This part of the process is critical and intensive. The process needs to raise the precision of appearance and illustration, to raise presentation performance, and to reduce information loss. It has to be pointed out that virtual models are tessellated models, because only a polygonal representation allows fast rendering in real time. The VP systems use different dataflow for manipulating virtual models in real time and converting data into the VP format is maintained differently from system to system, mainly depending on the application as discussed in [6]. In other words, the conversion is not standardized, and proposals do not exist in this direction, since virtual environments functionalities vary severely in applications. Simulation is the process of designing a model of a real system and conducting experiments with this model in order to understand the behaviour of the real system and/or evaluate various strategies for the operation of the system, [7]. Although the simulation experiment can produce a significant amount of data, the visualization of a simulated system provides a fuller understanding of its behaviour. In the visualization, key elements of the system are represented on the screen by dynamically changing positions as the simulation evolves over time

Large companies lack the time, and small companies lack the resources required to implement the technology and automation needed to compete in the marketplace. Desktop non-immersive VR systems features are far from the possibilities of immersive VR technologies, but a key advantage in desktop systems is that standardized computer techniques could be used.

3 SYSTEM ARCHITECTURE

In this research, the focus is on automatic generation of animation of warehouse activities from CAD system modelling into X3D environment for Web-based distributed environment. The main issue is that the process automatically generates simulation for Web services, and no additional knowledge or work is needed to perform simulations. To investigate and evaluate more than one solution, the change of parameters is provided, which is done in a manner that makes the visualization is a straightforward task.

The applications for simulation software managing problems typically present two conflicting issues. Pure simulation applications are user-friendly, but lack flexibility and accuracy. While simulation languages significantly improve model flexibility and accuracy, ease-of-use is sacrificed. By utilizing a simulation language and limiting the problem domain with a user-friendly interface, both fields could achieve great potential. Using templates is limiting the domain of a typical warehouse layout, and the parameters implied by the input data files. These parameters include a wide range of operational functions for all areas of the warehouse. The warehouse XML model implements many possible parameter combinations. The simulation provides the flexibility needed to accurately develop the warehouse model. The interface associated with the software provides for ease-of-use in setting up scenarios and running the model.

The Web-based framework provides a convenient platform for users to view and evaluate a model. A distributed design system can generate design models in an XML-style feature

representation to allow a Web-based system to perform viewing and manipulation, leading to two main features:

- Taking advantages of the effective utilizations of the Web and Java technologies makes the system independent of the operating system, scalable and service-oriented. The services located on the Internet provide an accessible way for the evaluation of warehouse activities.
- The configuration file represents an integrator with the definition suitable for X3D presentation.

An XML-style representation has been used to carry out some features for visualization and manipulations in the Web-based system. This format incorporates the characteristics of X3D and features to support Web applications. The XML-based information representation enables the system to be effectively adaptable to meet new developments in the Internet technology. The system and services are based on the Java-Servlet mechanism. With the development of some new Internet integration technologies, such as the Web service, it is necessary to explore new alternatives to integrate the current functions under the new system infrastructure.

All geometrical information, complete warehouse model with the configuration of walls and shelves is extracted from the CAD system with macro programming using the system's programming interface. X3D models generated directly from CAD systems, in general, are composed of many nested, complex and repeated structures. To accelerate the rendering performance of a system, global optimization of polygonal data is necessary. The application was coded to rearrange and optimize the X3D model; the geometry of parts is separated from appearance and additional information, such as view, background and navigation definitions. All data is stored in files. Since the direct translation from CAD systems into X3D models differ significantly, an individual interface is needed for every modelling system. Generally, the modelling systems offer only VRML record and translation from VRML to X3D is necessary. The macro program was coded to perform all needed actions: generate the hierarchical structure in XML, separation of geometry and appearances of parts, combine separated surfaces of the part into a single geometry file including optimization of geometry data. The optimization of the geometry data uses adopted algorithm described in [8] based on removing nodes, and performing triangular mesh decimation and undecimation. The optimization of data is necessary caused by the huge amount of data from modelling systems needing to be reduced for working on Internet applications.

The properly nested objects define the hierarchical structure and may contain references. With the DOM parser, it is possible to read the input file in XML, check formatting and semantic validity, built and present a complex hierarchical object structure with few lines of code. The configuration file represents an integrator with the definition suitable for X3D presentation. The semantic of the configuration file is following the X3D specifications and syntax. The basic object is defined, which could be a part, a grouping element or an element enabling multiple choices of objects at the same level. The structure of configuration file is described in [1]. A basic approach to recording the geometry specifications and added specifications for dynamic simulations is shown here.

The XML configuration file is built from Excel data sheets, which are commonly used in describing warehouse activities, with all necessary data for parameters to define each simulation scenario. We plan to develop a built-in editor that will allow easy changes of

parameters after every simulation run defining the new scenario. For now, the change of time is considered, as are the start time of different activities, manipulation times, moving velocity, etc.

When all the structure is completed, the macro program proceeds to simulation information. The macro appends to the configuration file the object definition of activity data with prescribed parameters with time frames. The macro allows the user to input the number of steps for interpolation of the motion (default value is 10). More steps result in smoother simulation and higher amount of data. The first line example could be seen in Figure 2.

```
Path.I loLim=0 upLim=25 keynum=10
[1.0,0.0,1.0,0.0,0.1,0.0,0]
[0.999,-0.039,-0.002,0.039,0.995,0.097,-0.002,-0.097,0.995,-1.743,1.084,-4.287]
[0.997,-0.078,-0.008,0.078,0.978,0.193,-0.008,-0.193,0.981,-3.434,2.646,-8.445]
[0.993,-0.116,-0.017,0.116,0.951,0.286,-0.017,-0.286,0.958,-5.055,4.668,-12.429]
[0.988,-0.153,-0.03,0.153,0.914,0.377,-0.03,-0.377,0.926,-6.587,7.129,-16.196]
[0.981,-0.188,-0.047,0.188,0.866,0.463,-0.047,-0.463,0.885,-8.013,10.002,-19.703]
[0.973,-0.221,-0.067,0.221,0.809,0.544,-0.067,-0.544,0.836,-9.319,13.254,-22.914]
[0.964,-0.252,-0.09,0.252,0.743,0.62,-0.09,-0.62,0.78,-10.489,16.851,-25.792]
[0.953,-0.28,-0.115,0.28,0.669,0.688,-0.115,-0.688,0.716,-11.511,20.753,-28.305]
[0.941,-0.305,-0.144,0.305,0.588,0.749,-0.144,-0.749,0.646,-12.374,24.918,-30.427]
[0.929,-0.326,-0.174,0.326,0.5,0.802,-0.174,-0.802,0.571,-13.069,29.299,-32.135]
```

Figure 1: Example of the file with interpolation data

```
<TimeSensor DEF='TS_Path_I' cycleInterval='10' loop='false'/>
<PositionInterpolator DEF='Plvrti_I' key='0.0,1.0,2.0,3.0,4.0,5.0,6.0,7.0,8.0,9.1'
keyValue='0 0 0,-1.743 1.084 -4.287,-3.434 2.646 -8.445,-5.055 4.668 -12.429,-6.587 7.129 -16.196,-8.013 10.002 -19.703,-9.319
13.254 -22.914,-10.489 16.851 -25.792,-11.511 20.753 -28.305,-12.374 24.918 -30.427,-13.069 29.299 -32.135'/>
<ROUTE fromNode='TS_Path_I' fromField='touchTime' toNode='MechlCmdI' toField='startTime'/>
<ROUTE fromNode='MechlCmdI' fromField='fraction_changed' toNode='Plvrti_I' toField='set_fraction'/>
<ROUTE fromNode='Plvrti_I' fromField='value_changed' toNode='vrti_I' toField='translation'/>
```

Figure 2: Generated interpolators and route definitions from Figure 1

Finally, the configuration file is finished and, at the end of the main object, the routing definitions are included.

These preparations were firstly done manually with much tedious and time-consuming work, but when all objects and scripts are prepared, the task is not so complicated if the configuration file structure is obeyed. To increase the efficiency of data preparation, the editor will be developed to manipulate parameters in configuration file more interactively. The extended database consists of geometry, simulation definitions, and the configuration file that keeps the structure of the product with attributes.

All the data are organized in files: geometry description, sensors, routing definitions, scripting nodes, interpolation data and material appearances with colours, textures, sounds, etc. The objects are represented by attribute pairs; the attribute name refers to the purpose, and the attribute value refers to the name of the file, which contains appropriate description to be included.

The simulation run is triggered by a start button to start the simulation in the browser window. During the simulation run, a full 3D animation of the warehouse scenario is shown from different viewing angles. This application provides input capabilities for setting up a number of customer scenarios and provides 3D graphical output for each. Because the application is developed to handle input parameter combinations simultaneously, the user does not need to

edit or compile the model code. Scenarios can quickly be set up and run to get comparative results and see what would likely happen in the real warehouse. When the simulation has completed running the defined scenario and the scenario is positively evaluated the XML file could be used to update the Excel data sheet. The scenario is presented in Figure 3 as snapshots.

4 CONCLUSIONS

The previous decade has seen the increasing use of computer technology for prototyping engineering designs and processes before manufacture or deployment. Providing the means of representing these systems as software programs enable multiple simulations to be run based on various inputs to the system. This methodology represents opportunities for the simulation engineer, such as the ability to vary system parameters or environmental inputs to reflect possible scenarios, and to do so exhaustively. Early verification through simulations minimizes the risk inherent in the design process by reducing the probability of discovering errors late in the development process. In engineering, the visualization of processes are of crucial importance. The use of simulation studies to better understand the dynamic behaviour of a system under investigation is at the core of verifying models early in the development process. Despite the amount of data that such studies produce, a 3D representation of the system creates a fuller understanding of system behaviour. The costs involved in virtual prototyping are inherently lower than doing a similar test on real objects. As an alternative for 2D simulations, more computer techniques are incorporated for visualizing and testing the functionality of the objects in the 3D world. Usage of standard Web-based technologies leads to easier, effective and more general applications suitable for small and medium-sized companies with limited resources in that field of research. Our approach is showing how Web application could be used to transfer models with structural and behaviour features directly to Web environment for evaluation. The use of single XML file covering the various configurations is found to be very suitable for versatile downstream applications.

Future work is focused on implementing the possibility for the user to add alternative partial solutions directly into the model, as fully defined sub-objects on a remote location. We will further investigate the possibilities to optimize the loading time in order to share the behavioural simulation via Web without the tedious extra work of preparing virtual prototypes for a particular solution.

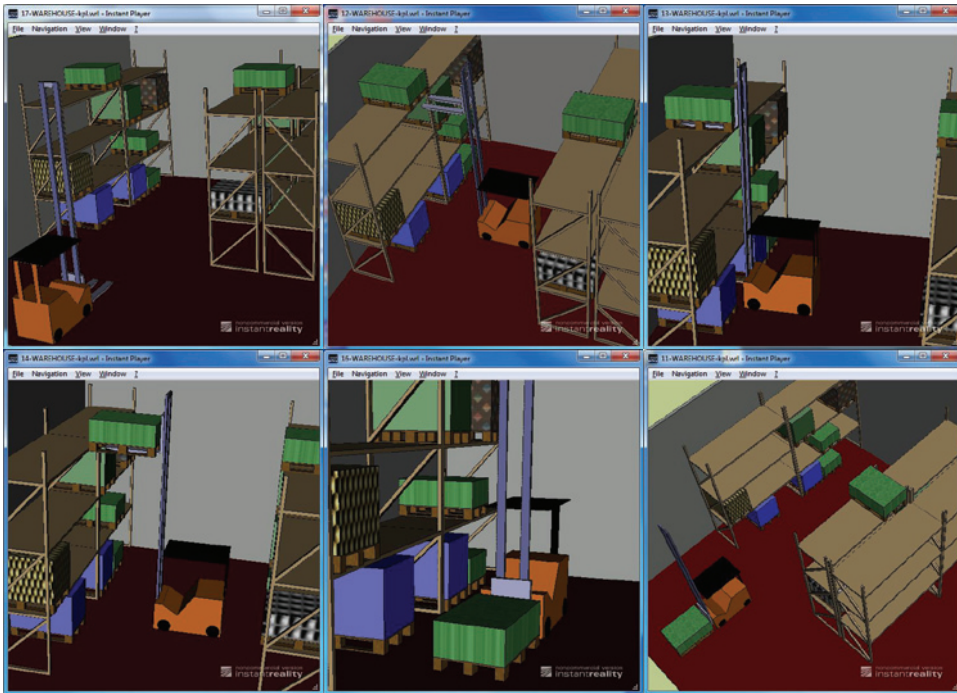


Figure 3: Snapshots of simulation in warehouse

References

- [1] **A. Jezernik, G. Hren:** *A solution to integrate computer-aided design (CAD) and virtual reality (VR) databases in design and manufacturing processes*, International Journal of Advanced Manufacturing Technology, vol 22(11/12), pp. 768 – 774, 2003
- [2] **G. Hren:** *Web-based environment for mechanism simulation integrated with CAD system*, Engineering with Computers, vol. 26, pp. 137-148, 2010
- [3] **J.L. Bijl, C.A Boer:** *Advanced 3D visualization for simulation using game technology*, Proceedings of the 2011 Winter Simulation Conference (eds. S. Jain, R. R. Creasey, J. Himmelsbach, K. P. White, and M. Fu), 2011
- [4] **D. Brutzman:** *X3D: Extensible 3D Graphics for Web Authors*, 1st edition, Morgan Kaufmann, 2007
- [5] **S. Choi, K. Jung, S.D. Noh:** *Virtual reality applications in manufacturing industries: Past research, present findings, and future directions*, Concurrent Engineering: Research and Applications, Vol 23, No. 1, pp. 40 – 63, 2015
- [6] **S. Mahapatra:** *Enhancing Simulation Studies with 3D Animation*, AIAA Modeling and Simulation Technologies Conference, Portland, Oregon, 2011
- [7] **R. Shannon:** *Systems simulation: the art and science*, Prentice Hall, 1975