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CONFIGURATION, SIMULATION AND ANIMATION OF MANUFACTURING SYSTEMS VIA THE INTERNET

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ABSTRACT

In the light of growing demand for individualized products, configuration systems are becoming increasingly important. Most interesting are configurators that can be accessed over the Internet. They can be used by sales representatives and customers independent of location and time. In this paper, a new electronic service for configuration, simulation and animation of manufacturing systems is considered. It allows to present, test and optimize manufacturing systems via the Internet.

1 INTRODUCTION

Manufacturers of sophisticated technical plants know the situation: their customers are doing investments worth millions without first scrutinizing the ordered items. Usually, the ordered items are specific configurations, exactly tailored to the demands and needs of the customer. Virtually, configurations are unique in that manufacturers produce to customer orders. On the other hand, the customer would like to know in detail before the contract is made, how the plant will look like and what its performance will be. Between both parties, the manufacturer and the customer, there is often a considerable uncertainty and imbalance of information. More often than not, the customer bases his decision on feelings, rather than on exact data and comparisons.

Here, simulation can build a common ground for communication (see e.g. Arinze and Burton 1992, Gour and Grover 2001, März and Richter 2001). The customer contributes to the basic design of the plant by bringing in his ideas about structures and dimensions. This basic design is mapped into a simulation model of the planned manufacturing system. The advantages of simulation are obvious. It provides an analysis of the dynamical behavior, a dimensioning, the interactions between modules of the overall plant, an identification of bottle-necks and weaknesses as well as a proof of functionality and performance limits. However, there are two major drawbacks in a straightforward application of the simulation. Firstly, since the plants are made to customer orders, there is a considerable effort in building and validating the simulation model. As no plant is the same as the one before, no simulation model is the same as the one before. Secondly, the results of the simulation model are used by sales personnel virtually all over the world. As sales persons are usually no experts in simulation, the tool should be easy-to-handle from wherever it is desired.

This paper presents a solution to the above-mentioned problem by combining Internet-based configuration with Internet-based simulation and animation. Therefore, we take advantage of and combine two important developments in simulation of the past few years: an automated database-driven, (that is, generic) generation of simulation models (see Xia 1994, Richter and März 2001, März and Richter 2001, Randell and Bolmsjö 2001) and the web-based simulation (see Fishwick 1997, Page 1998, and Kuljis and Paul 2000). For explaining the tool proposed we intend to proceed as follows. In Section 2, we show how the trend towards configurable modular solutions, pursued by many manufacturers of sophisticated technical plants, can support automated database-driven generation of simulation models (generic simulation). We also consider how the use of configurator and simulation can be integrated into the sales process. Based on a brief review of generic simulation given in Section 3, we present in Section 4 the architecture of the configuration and simulation system. In Section 5, we show an application example and finally, in Secrion 6 we summarize the results and draw conclusions.

2 TOWARDS CONFIGURABLE MODULAR SOLUTIONS

To be able to present the customer with a wide range of systems, the plant components must be designed as modules that are part of a building-block system. During the configuration process, the modules are combined into an individual system. The use of modules and components makes it possible to provide a great variety of machines at lower costs.

Configuration systems make it possible to design and display products from electronic product catalogues on the basis of defined rules. Configurators allow to slash the time from initial customer contact to order placement. The sales representatives use the configurator to quickly specify the demands that customers place on a manufacturing system. The desired system features are entered via a user interface. The configuration process is supported by multimedia contents, CAD drawings, etc., which are generated by the configuration systems from the company's BOMs (bills of material). The basic idea behind this procedure is to store the knowledge required for the design process in the configurator and support the customer with automated proposals. Hence, configuration systems enable even field workers without expert knowledge to provide the customer with details about feasibility and price. At the end of a sales talk, a binding offer can be submitted, which may also include multimedia components. Configuration systems improve the information flow between customer and manufacturer, and shorten the processing times between initial contact and the preparation of tenders.

However, there is a drawback to such customized systems as compared to standard systems: a pre-guarantee for fulfilling the performance demand cannot be given. In other words, we are not only interested in the visualization of configured manufacturing systems, we also look for support in selection and dimensioning. This is particularly important as the variety of configurable systems is large and no experience exists regarding the properties of the total system. To solve these problems, simulation and animation methods are increasingly used. In the past, animation in sales and marketing has mainly focused on displaying 3D-CAD drawings and illustrations of the modules. We suggest using to use a configuration-specific simulation model, which includes a 3D animation, in the sales process. While configuring the manufacturing system, the database for the simulation model is being prepared in the background. By means of this simulation model, it is easy to carry out customer- and product-specific simulations. As the descriptions of both the system and the system load is being varied during configuration, various alternatives can be tested until the best option for the customer is found. Since the system can be used over the Internet, it can in addition be operated from virtually anywhere a potential customer is situated. To run such an easy-to-configure simulation model requires that all necessary data for building it are stored and can be accessed in an appropriate manner. An approach to achieve this is an automated, database-driven, that is, generic simulation models. In the next section, such generic simulation will be briefly recalled.

3 GENERIC SIMULATION OF MANUFACTURING SYSTEMS

Traditionally, the topology and structure, as well as the component description of the system are fixed in the simulation model. That means these data are firmly linked to the model by the simulation language of the simulator. Clearly, this makes building and maintaining of larger and more complex simulation models difficult. A better solution seems to be to create the simulation model at run-time out of a database, in which all necessary data can be stored and easily updated (see Richter and März 2001, Randell and Bolmsjö 2001 and cited references). Such kind of simulation models are also called generic simulation models, with the main distinguishing feature being that both the description of system (structure) and system load (parameter) are stored in the database. The data is only read and interpreted when the individual simulation model is generated. This process is controlled by the generic simulation model (Figure 1).

To run a generic simulation of a manufacturing system, it is necessary to have an extensive component library (including machines, queues, conveyor systems, etc.) available. This component library consists of a collection of defined, documented and coordinated manufacturing processes and standard objects. During the configuration process, the components are dimensioned, selected and parameterized, and the material flows are defined. By joining the elementary components, an abstract model of the manufacturing system is produced. Since manufacturers of sophisticated technical plants are increasingly building their products out of modules, these modules form the base from which parameterable simulation building blocks can be derived.

When making simulation a constituent part of a company's planning process, it is advantageous to adopt the data from internal information systems. Thus, updating is left to proprietary systems and redundant data storage is avoided. In the next section we give a detailed description of the architecture of generic simulation and show how configurators are linked to the Internet.

4 ARCHITECTURE OF THE CONFIGURATOR

General requirements of information and communication architecture are high accessibility, reliability, scalability and openness towards heterogeneous systems. Current architectures are characterized by service-based models, which can be accessed by users independent of time, place and platform (see e.g. Cook 1996, Cohen 2000). To realize these ideas in the proposed system, the architecture of the configurator is fourfold: the user domain, the portal domain, the data domain and the simulation domain, see Figure 2. Such an architecture is based on the architecture for generic simulation given in the previous section. In addition, there are elements for enabling the configuration process, for

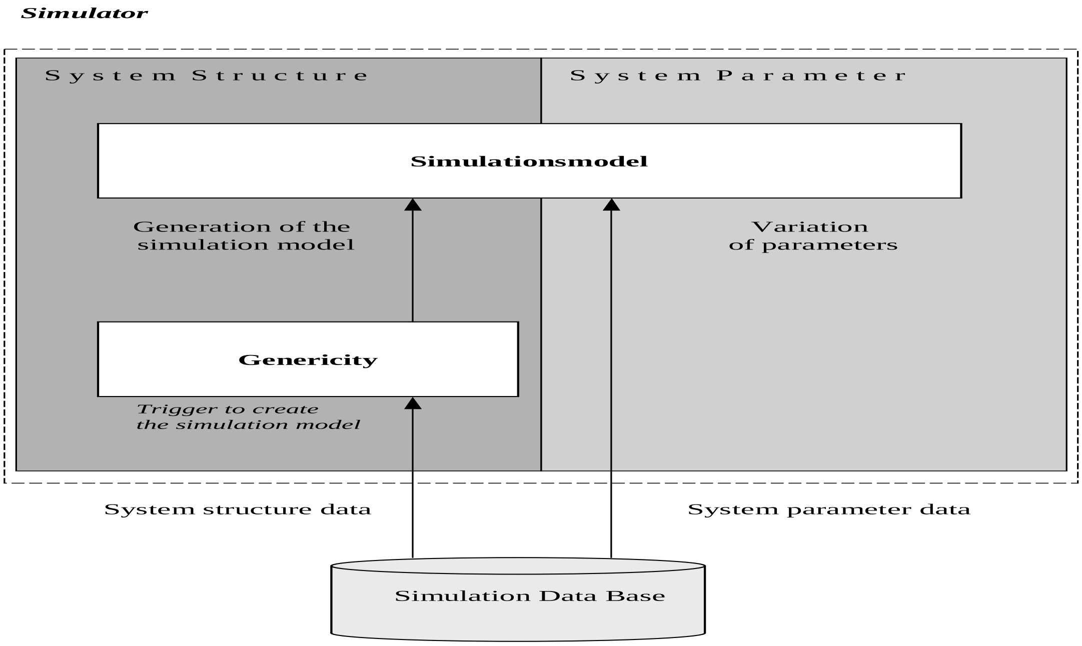

Figure 1: Generic Simulation

administration, start and interpretation of simulation runs, and for user administration. In that way, the architecture is similar to standard architectures for web-based simulation (e.g. Marr et al. 2000, Guru, Savory and Williams 2000), which is extended by components to manage and carry out generic, database-driven simulation.

The user domain only requires a browser for logging into the portal domain by HTTP protocol. Optional access can be given by SSL code. Within the browser, there is a Java applet running, performing the interactive configuration process with the user and writing the results of the configuration in a database for further usage. In the course of creating the generic simulation model for the specified configuration these data will be retrieved.

The portal domain is an e-service platform serving as user administration, simulation service, as well as session and access control. It consists of a web server and an application server. While the web server controls and performs the communication over the Internet, the application server houses the applet used as a GUI and containing the configuration logic. The portal domain is linked to the data domain. It consists of several databases, namely the configuration database containing all necessary information to specify one specific configuration for which its generic simulation model is to be created, the structure database containing all information necessary to specify any module in any configuration, and a query which can record simulation jobs. Based on the configuration the user has specified in the web browser, it writes a configuration database using the information about the modules actually taken from the structure database. In this structure database, structure description for all modules usable in the configuration process as well as default values for parameters further specifying the modules are stored. The structure database is linked to the enterprise information systems so that updates for the modules resulting from re-engineering can be passed through the structure database. In addition, the application server creates a simulation job for the configuration in the query after the user has finished his configuration process on the GUI.

In the simulation domain there is a launcher and the simulator. The launcher checks if there is a simulation job in the query. If so, it further checks which simulator is free and allocates the job. Triggered by this, the simulator pulls all the necessary information stored for a particular configuration from the configuration database and creates the generic simulation model. After the simulation is finished, the results are given back to the data domain and then to the application server. Simulation domain and data domain are entirely decoupled. Communication between the domains is realized by Java-RMI only. Therefore, it is possible to lash distributed simulation engines, joining them to the architecture. Thus, an effective utilization of available simulator licenses can be realized. Furthermore, the architecture is open for all simulators possessing a SQL interface. Separation between portal domain and simulation domain allows parallel and hence rapid simulation of different configurations. This is an advantage in conducting simulation studies.

It should be finally mentioned that the overall system for configuration and simulation of manufacturing systems

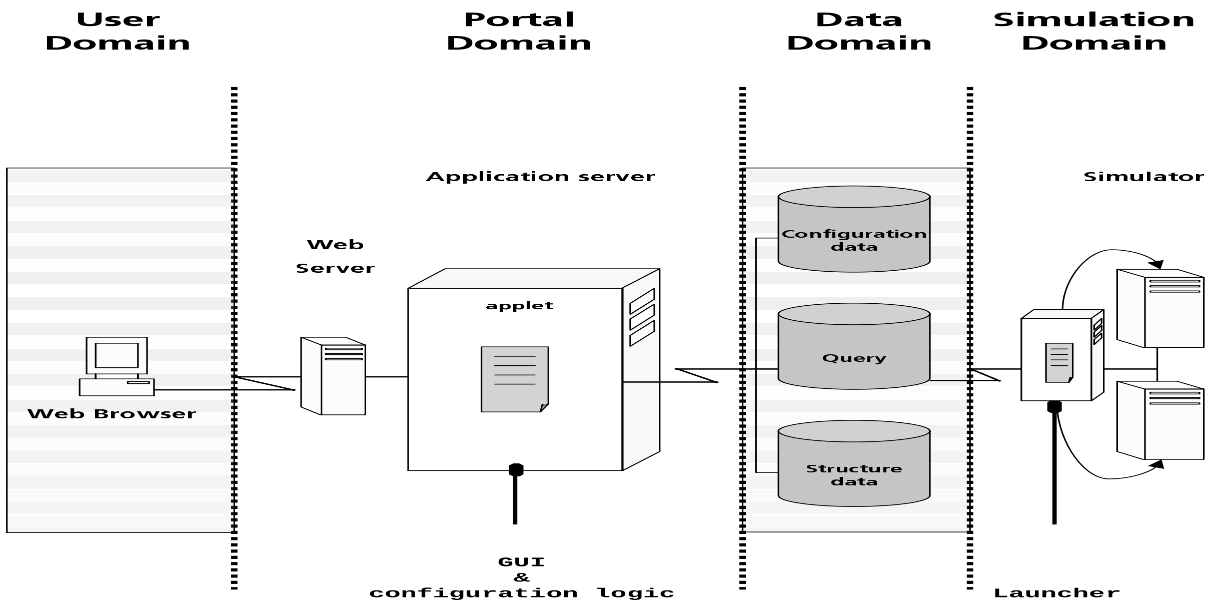

Figure 2: Architecture of the Internet-based Configuration and Simulation System

works entirely automated and can be accessed by several users at the same time.

5 APPLICATION EXAMPLE

In the previous sections we have considered architectures for generic simulation as well as for an Internet-based configuration and simulation system, the configurator. We now give an implementation example. The conceptual knowledge was put into practice in a pilot project with a medium-sized company. The goal of the Internet-based configuration and simulation project was to design modular components for material flow and testing of printed circuit boards.

In the context of this pilot project, the existing tool was adapted to meet the requirements of the customer. This customization included the adaptation of the generic simulator, adjustments of the configuration logic to the modular structure of the simulated plant and the provision of a user-specific result display. A crucial part of the solution was the fact that the configuration of the inspection facilities could be done interactively via the Internet (see Figure 3 for the GUI). Within the configuration layout, the user can select a module (which are collected in module groups) from a menu. Along with the module, the user gets an image of the module (to enhance recognition) and the parameters set as defaults in the structure database. These defaults can be overwritten, hence imposing an individual parameter set for a specific module. Moreover, the user can open an existing configuration and repeat the simulation, possibly with a changed parameter set. Thus, simulation studies can be carried out. After configuring the plant, the simulation is carried out to determine the dynamic parameters. The latter is made available to the user via the Internet and includes not only standard quantities in logistics, such as utilization and cycle times (which are presented graphically on the result page due to data volume considerations; optionally the full result data can be downloaded), but also a 3D animation as an AVI movie (Figure 4). This procedure makes it possible for each user to get a clear idea of the effective total operative performance and of the appearance of the configured plant.

6 CONCLUSION

This paper described the simulation-based configuration and animation of a manufacturing system via the Internet. In order to offer customers a large variety of individual manufacturing systems, modular components are an absolute necessity. During a configuration process, these modular components are combined to create a customer-tailored system. The subsequent simulation helps to dynamically assess the total operative performance and to present a 2D/3D visualization of the system. With the help of different configuration options, the system provider can demonstrate to his customers the different performance measures a system is able to achieve. The use of configurators helps the system manufacturer to distinguish himself from his competitors in soliciting business. The potential buyer benefits from the visualization as it gives him a good impression of "his own" system. Besides, the simulation-based performance measures provide additional security.

Configurators have proven a fair opportunity to reduce time from initial customer contact to order placement. The

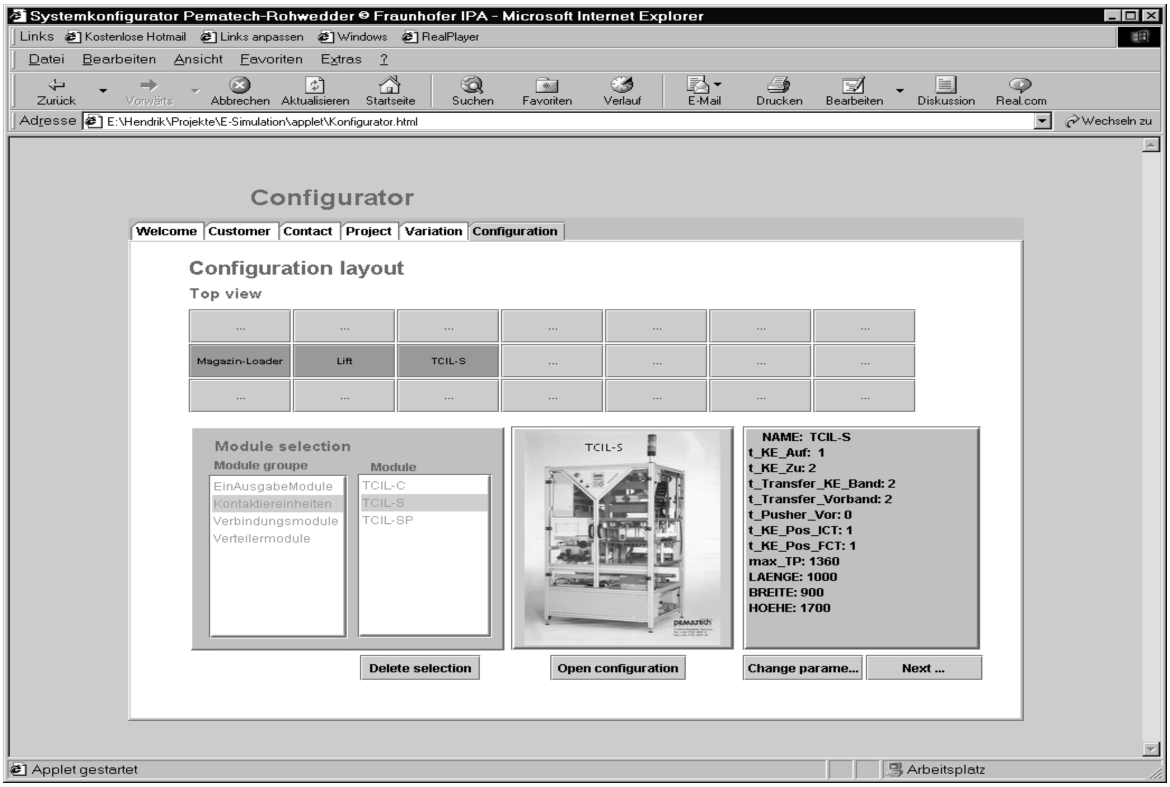

Figure 3: GUI of the Configuration System

necessary technological resources are available on the market. However, the integration of such systems should be accompanied by optimization measures in sales, operation planning and product design. Configuration systems will probably prove a success on the market and shortly become a standard service in sales and distribution.

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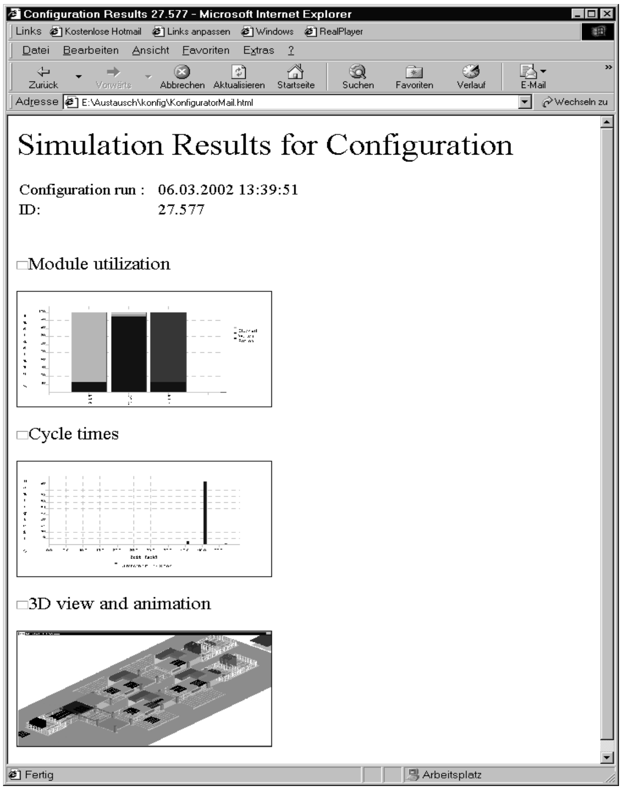

Figure 4: Results of the Simulation of the Configured System

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