AN INTEGRATED OBJECT MODEL AS A WORLD OF MODEL COMPONENTS FOR AN ACTIVITY NETWORK BASED SIMULATION APPROACH

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ABSTRACT

One of the main obstacle for an integrated use of simulation over different planning areas and stages are the various views on a production system. Therefore, a world of model components is developed, which enables the co-existence of different views and levels of detail in the same simulation model while maintaining its consistency. This is achieved by combining a network based simulation approach with the object-orientated technology. The fundamental idea is to offer the opportunity to re-use existing models for the investigation of different aspects of a production system. The approach is abstractly described as a generic object model and is thus, independent from a concrete simulation language, tool or environment. This paper describes the generic object model as a world of modeling components of an object-orientated simulation approach. Furthermore it discusses the modeling requirements for such a simulation approach.

ACCEPTANCE OF SIMULATION TOOLS IN PRACTICE

For the design and control of production systems, simulation has proven to be a powerful tool. However, investigations of the market situation have shown that many companies are not willing to use simulation as a permanent planning tool (Schmittbetz 1998, p. 18; Zülch et al. 2002, p. 39). One of the most named reasons for this is the expenditure associated with modeling a production system (Rabe 1999, p. 3). The problem is that most simulation tools which are available on the market today, do not support the re-use or exchange of models e.g. exploiting them for different planning aspects.

In order to realize the exchange and the re-use of models there can be used two fundamental possibilities. Either one defines a standard interface between different tools or one combines the different views of a production system in one world of model components, e.g. the view of material flow, the view of manufacturing or the view of personnel planning in one simulation application. During the development of such a simulation concept the problem of semantic compatibility is likely to occur. Each view of a production system shows different parts of it. If one wants to combine these views, the world of model components, on which the simulation application is based, has to contain the main elements of all these views. If an additional task of a simulation tool is to reach a flexibility similar to that of other planning tools, e.g. operation plans or plain text descriptions, the modeling methodology has to support a step by step development of the simulation model. In this case, it should be possible to simulate the model in every development phase. Thus, the simulation concept has to support various levels of detail and also the addition and removal of model parts.

THE IDEA OF AN INTEGRATED OBJECT MODEL AS A WORLD OF MODEL COMPONETS OF A PRODUCTION SYSTEM

In order to take a step towards a solution of the described problems, an object-orientated simulation concept is under development at the ifab-Institute of the University of Karlsruhe. The fundamental idea is the development of a generic world of model components (cf. VDI 3633, p. 11) of a production system including the simulation functionality of the model's elements. In this world of model components, various application views are combined. Thus, the derived models can be used in different planning steps.

For the development of the world of model components object-orientated modeling principles were chosen. With the help of the object-orientated technique of specialization the functionality of an object model can be structured hierarchically. In this manner, abstract object classes may be defined with more universal functionality compared to traditional approaches. This universal functionality can be adjusted to the requirements of a specific application field, with the help of specialization.

In this way, common features and variations in different application views can be brought into a defined context. Separate objects can be combined using the principle of composition. Thus, more complex functionalities can be realized.

Experience has shown that the hard part of representing a production system is to depict the processes and their respective control because these aspects are quite abstract and it is rather difficult to get an intuitive correspondence between model and reality. One possibility is to depict the processes by modeling them based on activity networks. This technique is found mainly in project management and business process modeling (Schmid 1998, pp. 20). It makes intuitive handling of the activities together with their releases and dynamics to a great extend possible.

For the basic generic model

- object-orientated modeling and draft techniques combined with an
- activity network based simulation approach have been used.

Additionally, the generic object model will realize the following properties:

- The object model should support the co-existence of different views and levels of detail and should allow the hierarchical structuring of simulation models.
- The step by step modeling of simulation models should be made possible while preserving the consistency of the model.
- The most important logistical and monetary key data should be consistently available throughout all modeling views and hierarchical levels.

In addition to the development of the world of model components, one further aspect must be considered. In order to apply the developed world of model components in practice, it must first be realized as a software application. This was done with the newly developed simulation tool *OSim* (Object-Simulator). Following the fundamental idea to make a simple, practical usage of simulation possible, concepts which transform the simulation application into an easily accessible and generally available planning tool must be developed. This encompasses not only the technical fundamentals, but in particular also the concepts for the modelling. In order to achieve a suitable acceptance among the users and to support the re-use of model parts, the modelling of new and the adaptation of already existing simulation models must be supported by appropriate modelling concepts.
It is thereby important to develop concepts for the user interface which make simulation intuitively accessible, even for inexperienced users. A further problem area which was picked up within the development process is the appropriate graphic support of a hierarchical modelling of production systems. A flexible handling aid, which can represent in particular modelling elements which are imbedded in one another in a nested manner, and which allow for a free selection of the view or the degree of detail of the representation, was developed. It also realizes methods which can be used to "copy-paste" objects from various models and configure them into a "new" simulation model.

THE WORLD OF MODEL COMPONENTS

The step by step development of the generic world of model components represents the central aspect of the developed simulation procedure. The development of the object model was divided into 5 steps (Figure 1). Each of the steps had the task of integrating a certain view into the world of model components (Zülch et al. 2000, pp. 371).
In the first development step a process-orientated view was formed. The modelling of enterprise processes based on activity networks were thereby the focus (cf. Jonsson 2000, pp. 55).
In the second development step a resource-orientated view was pursued. Object types which allow industrial resources, personnel (types) and so-called quantity resources to be modelled were defined; the latter helps represent e.g. stock or buffer places. The reference object between the resources are able to represent even the complex assignment of machinery resources as well as personnel structures.

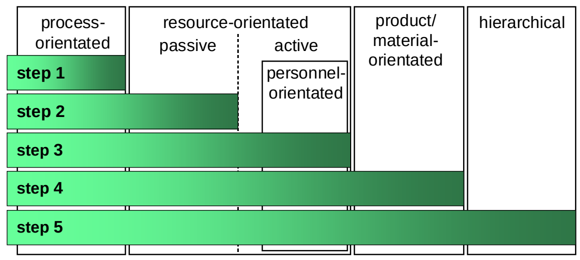

Figure 1: Development Steps of the Object-orientated Model of a Production System (Jonsson 2000, p. 23)

In order to account for the imbedding of dynamic analysis methods passive and active resources are differentiated. A passive resource behaves e.g. passively within the context of a dynamic situation, meaning it does not possess the functionality to be able to intervene in the dynamic sequence of the processes. In order to be able to illustrate the behaviour of resources, such as e.g. persons, in a detailed manner, it is necessary that the resources participate in the sequence of processes actively. For this reason, a concept allowing resources, so-called actors, to take on an active role was developed. It is thereby intended that the resources can be assigned to various different action instructions or action logics.
The goal of the fourth development step is to give the materials which are involved in the processing representation and thus include a material-orientated view.
In the fifth and final development step a hierarchical view, which to a certain extent run orthogonally to the previous concepts, was integrated into the generic object model.

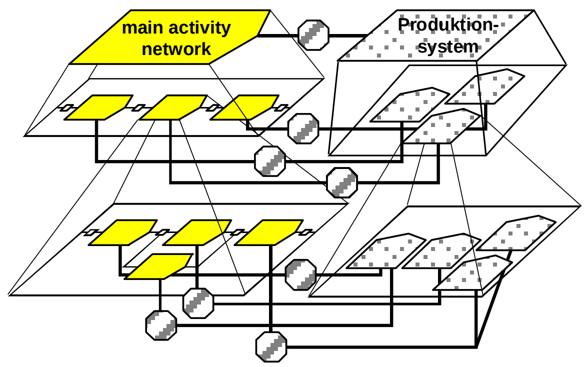

Figure 2: : Example of a Hierarchical Simulation Model

Three aspects of the hierarchical structuring were differentiated: The modelling concepts for processes with so-called activity networks were expanded in such a way that they could be nested in one another arbitrarily, as represented on the left-hand side of Figure 2. For the resources so-called collection objects were defined, with whose help they could be aggregated into e.g. departments or segments.

DISCUSSION OF THE SIMULATION APPLICATION *OSim*

Since the described model can only exist in a conceptual form, a software transformation and an appropriate implementation into a simulation environment into which the world of model components can be embedded are required (cf. Figure 3). In order to create simulation models objects from the model elements of the generic world of model components are instanciated. These must then be administered and persistently stored.

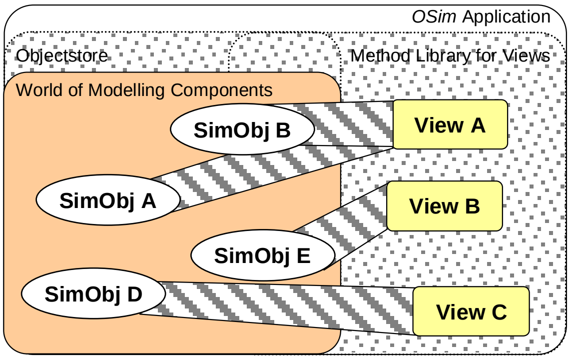

Figure 3: Architecture of *OSim*

For this an objectstore, which contains the corresponding methods, was implemented. Objects are applied, edited and linked by the user with the help of graphical interactive views. The simulation environment provides the basis functionality for such views.A view always represents a certain modelling level of an object and depicts this modelling level correspondingly. From the user's point of view it is fundamentally possible to open a view for any arbitrary object, whereby usually several differing views are available.

A key theme in the development of the simulation environment was to configure the world of model components with the object-orientated concept of specialization so that it would be arbitrarily expandable. One problem that usually occurs after the expansion of such a generic object model, is that all views which deal with the changed object must be aligned accordingly. In order to avoid this a compiler which creates descriptive information was realized. This descriptive information allows views to be created dynamically. The standard is to provide for each defined object typed automatically a so-called generic view. Such a view provides the rudimentary possibility to process an object. Due to its automated generation it is mostly unstructured and thus complex.

In addition to the automatically generated views described, the simulation environment also offers the possibility to configure the views freely. The previous functionality distinguishes itself through its automatic generation of views, it is however not suitable for the obvious and effective manipulation of objects which are linked with each other, since no graphic assignment of the objects can be realized with them.

In this context a graphic modeller for all types of graphically assigned objects was realized, which in particular supports a hierarchical modelling of objects across an arbitrary number of recursion levels. Based on this graphic modeller various views for the graphic modelling and linking of the elements of the world of model components (throughput diagrams, resources etc.) were realized in the modelling tool.

For this purpose Figure 4 illustrates an example od a throughput diagram which was created using this graphic modeller. Each node represents an activity which is

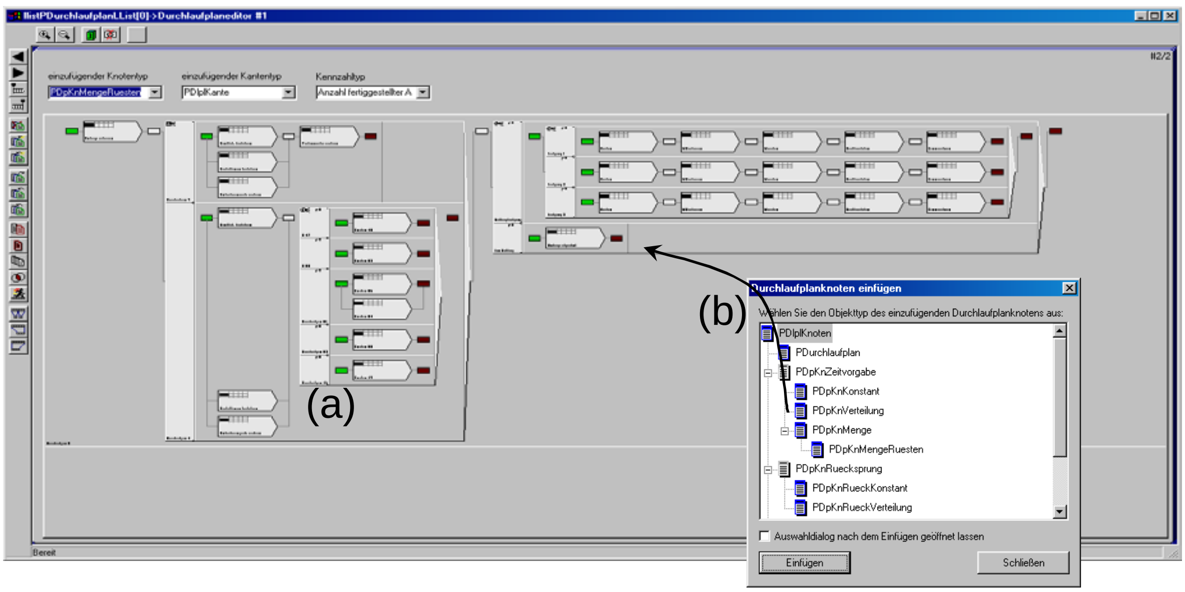

Figure 4: Modeling Tool of *OSim*

attributed by its time demand. The modelling tool supports the hierarchical modelling in such a way that the graphic icons, which in these cases represent the nodes of the actual modelled activity network, can in turn contain icons (cf. Figure 4, detail a).
A general problem which often discourages planners from applying simulation is the expenditure associated with the creation of the models. In this context, attention was paid in particular to the simplification of the handling and the user guidance during the realization of this modelling tool. The graphic modeller arranges the nodes using a special assignment technique automatically so that the user can concentrate on the actual modelling content and does not waste time with the troublesome assignment of objects. Furthermore, a zoom function, copy-paste functionality and the insertion of network diagram elements with drag-and-drop are supported (cf. Figure 4, detail b).
The evaluation functionality was also added to the viewer of the configuration tool. In this manner the object related key figures can be displayed directly at the modelled object. This form of representation allows the user to carry out the evaluation with direct reference to the model construction. Various representation forms for key figures, e.g. using bar graphs as well as on-line-animation or gantt-charts representation of resource utilization are available for the dynamic display of key figures (cf. Figure 5, detail d).

EXAMPLE MODEL OF A GEAR BOX PRODUCTION

After describing the conceptual world of model components, the simulation tool *OSim*, that implements it. is demonstrated. The model deals with the manufacturing of gear boxes and their respective order processing and design activities. It is only a simple model and the given example does not claim to be a full simulation investigation.

In Figure 5 the model is shown. On the left hand side the activities for the order processing and design (detail a) are shown and the activities for the manufacturing (detail b) on the right hand side. The model of order processing/design contains in the alternative node PA1 the possibility for a new or adapted design. The structure of the alternative activity networks are mostly the same, but the operation times are different. Alternative node PA2 features a probability branch. Either the order is given (80 % possibility) or it is not given (20 % possibility).
Manufacturing is modeled within the alternative node PA3. There are three possible alternative paths due to different possible operational unit combinations which offer different capacities and qualities.
Next, passive resources are added (detail c). In the order processing and design part the personnel resources are the released elements, and in the manufacturing part they are the machinery equipment. The modeled resources dominate the operation times in each case. In the shown state of the model, only passive resources are used.
During the simulation run, an entity object accompanies the processes. At alternative node PA3 it intervenes in the simulation process. At this point, a decision has to be taken which alternative path the order has to take. In the described simulation run the entity object decides, first considering the available capacity at first. If this decision offers two different paths, it decides based on the quality level which an alternative path offers.
In Figure 5 the activity network is shown after the simulation run. At the node objects there are activated bars that portray the activity related average lead times (detail d). In Figure 6 (detail a) the average lead time of the main activity network is depicted, and in Figure 6 (detail b) the lead times of the node objects of the main activity network are shown. Here the different aspect of the average lead time

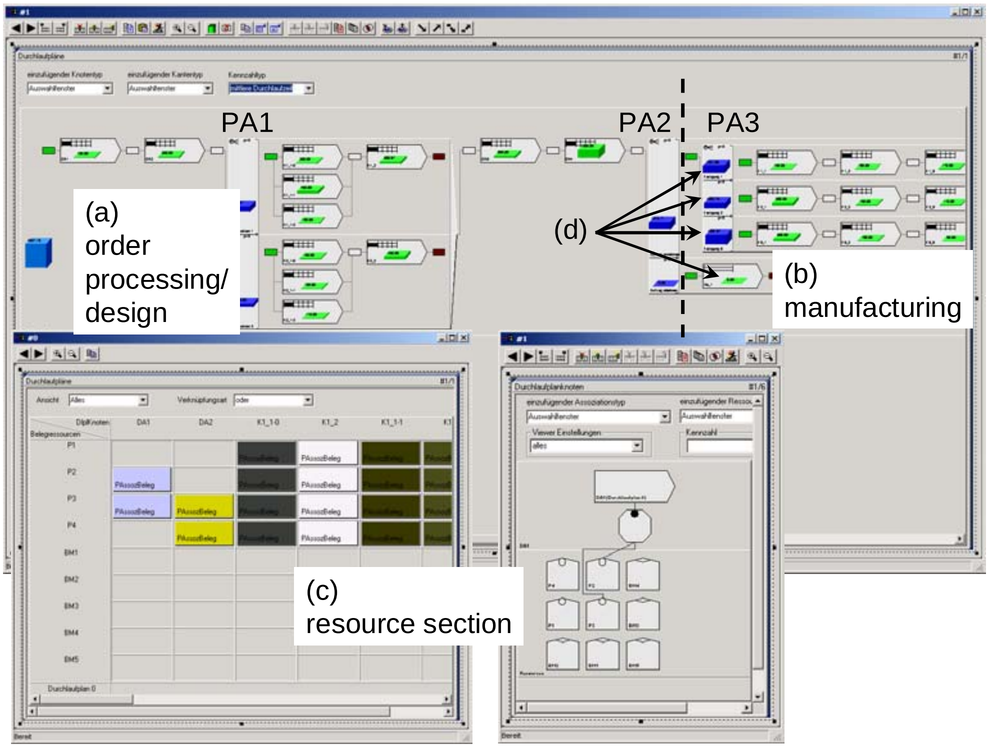

Figure 5: The Gearbox Model

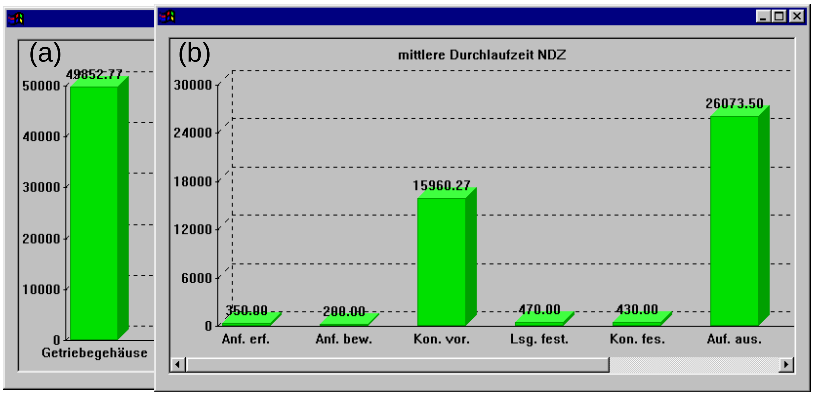

Figure 6: Average Lead Times of the Object Nodes and the Main Activity Network

in hierarchical simulation models can be observed. The entire result in (detail a) is not the sum of the node objects lead times in (detail b). This is due to the fact that the top level activity network calculates its average lead time with the help of its recorded process protocols and not with the help of its respective node objects.

In the given example the model is not very detailed. It does not use the whole functionality e.g. modeling of active resources or differentiated personnel structures.

As a next step, the model can be validated and adjusted using the real system for calibration. In a case where the results are in the same value range, the model can be used for further investigations, if not, the model should be improved, step by step, until the results correspond.

RESULT AND OUTLOOK

The functionality of this object-orientated simulation approach is demonstrated using the model described in the chapter before. With the help of object-orientated design methods, the generic world of model components can easily be extended. Thus, it can be adjusted to concrete problems of practice.

As a summary, it can be stated that the combination of activity network based modeling principles and object-orientated design techniques are suitable as a base for a generic simulation model for production systems. With the developed object model the foundations are layed to use simulation as a permanent planning tool.

In order to reach this goal, further concepts are required. Particularly there are concepts necessary to support the automatical or semi-automatical model generation out of data stored in databases of production systems. Some fundamental concepts for coupling the simulation tools *OSim* and databases of production systems are already implemented (cf. Zülch and Fischer 2002, pp. 55). However, if the object model could be integrated into a production data base, it should be possible to configure simulation models out of it, perhaps with the help of drag and drop. Thus, the creation of a simulation model would be much easier than at the present moment.

So far, the simuation tool *OSim* has been used for the evaluation of flexible working time models for service enterprises. This application has shown that the developed generic model is not only limited for the modelling of production systems.

REFERENCES

Jonsson, U. 2000. “Ein integriertes Objektmodell zur durchlaufplanorientierten Simulation von Produktionssys-temen.“ Aachen: Shaker Verlag. (ifab-Forschungsberichte aus dem Institut für Arbeitswissenschaft und Betriebsorganisation der Universität Karlsruhe, Band 21)

Rabe, M. 1999. “Beginnt ein neues Zeitalter der Simulation?“ In *Simulation und Visualisierung '99*, ed. O. Deussen, V. Hinz and P. Lorenz. San Diego (CA) et al.: The Society for Computer Simulation International, 3-18.

Schmid, C. 1998. “Beitrag zur Modellierung und Analyse dynamischer Unternehmensmodelle.“ Aachen: Shaker Verlag. (Forschungsberichte aus dem Institut für Rechneranwendung in Planung und Konstruktion der Universität Karlsruhe, vol. 98, 1)

Schmittbetz, M. 1998. “Simulation wird zum Triebwerk für Innovation.” In *VDI-Nachrichten*, 24, No. 52, 18.

VDI 3633, Blatt 1, Entwurf, 2000. “Simulation von Logistik-, Materialfluß- und Produktionssystemen.” Berlin, Beuth Verlag.

Zülch, G. et al. 2000. “An integrated object model for activity network based simulation.” In: *Proceedings of the 2000 Winter Simulation Conference*. (Orlando, FL) IEEE, Piscataway, NJ, 371-380.

Zülch, G. et. al. 2002. “Hierarchical simulation of complex production systems by coupling of models.” In *International Journal of Production Economics*, No. 77, 39-51.

Zülch, G. and Fischer, J. 2002. “Datenbankunterstützte Modellbildung.“ In *Industrie Management*, 18, No. 3, 55-58.

BIOGRAPHY

GERT ZÜLCH, born in 1946, studied mechanical engineering at the University of Technology at Brunswick, and Industrial Management at the Superior School of Technology at Aachen, Germany. In 1985, after 10 years of experience in research and industry, he became professor and head of the then newly founded ifab-Institute of Human and Industrial Engineering at the University of Karlsruhe.

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