KNOWLEDGE GENERATION IN MODEL BASED PRODUCTION SYSTEM DESIGN

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ABSTRACT

In an application-oriented approach, modeling can be seen as a means of generating knowledge about a system itself. That knowledge may then be utilized to determine possible and adequate changes to the system itself. With modeling techniques gaining importance in academic research as well as industrial application, it becomes necessary to examine this aspect of modeling. The paper will examine the aspects of knowledge generation during modeling and compare them with problems as encountered in industrial practice. Thereupon it will lay out some basic requirements and success factors for model based approaches in systems design.

Keywords: Systems design, knowledge generation, modeling.

1 INTRODUCTION

Models and modeling methodologies are a core tool for production systems design. The passed two decades have seen a major growth in importance of modeling methodologies in academic research. On first hand, research was and still is focused on deriving a comprehensive framework covering all aspects of systems design, i.e., technology, organization and management. The most noted example of this attempt is the notorious ESPRIT CIMOSA [ESPRIT consortium AMICE (1993)] initiative of the European Communities in the 1980s and 90s which dominated more than decade of European research in production systems design. Besides the academic efforts several simulation tools were introduced with increasing impact on industrial practice. Simulation tools show a more evolutionary development from partial models, e.g., 3D volume simulation of objects, to a limited combination of partial models, e.g., design of logistics systems combining flow optimization and physical handling.

Examining today's situation in practice, one tends to realize how little impact academic research had in the field of industrial application. Even though in partial fields of manufacturing, today comprehensive modeling tool-sets are used in industry, e.g., assembly line design focussing on technological issues or business process modeling in the context with organizational issues, their application is rather limited to an exclusive number of enterprises. Determining the causes, one easily can find, that most research by far to much focussed on the model itself and did not focus on its utilization throughout a real-life design process and the systems life cycle. Also the search for a complete, comprehensive framework did distract attention from the fact, that – even though incomplete – techniques for partial modeling of a limited number of aspects should first be utilized and examined in respect of knowledge generation in practice.

2 CRITIQUE OF MODELING IN PRACTICE

To sum up: Most modeling approaches as derived in academic research are far to complex to fulfill the requirements posed by the demand of generating knowledge for practice. Based on several discussions with systems engineers a basic critique of modeling in practice can be summed up in the following statements:

- The quality of a model can only be determined to a limited degree (mix-up of semblance and reality).
- Simple observations have to be modeled with great difficulties (models more complex than reality).
- Complex observations, e.g., influence of creativity or experience on decision making or collective decision making, can only be modeled

with great difficulties and often not definite (lack of precision).

– The high degree of formalization necessary for modeling leads to a rather formal and technical observation (tendency to formal thinking).
– Modeling reality always leads to a limited perception (limited focus).
– Models need to interpreted by varying means according to qualification and background of the observer (dependency from observer).

To provide a deeper insight in academic and industrial practice we will focus on the problem of "shop floor scheduling" as an example for the application and development of models as means of problems solving and generation of knowledge.

3 MODELLING IN THE FIELD OF SCHEDULING RESEARCH

For a long period, research on production and operations management concentrated on the solution of the scheduling problem at shop floor level. Traditional quantitative approaches, as present in Industrial Engineering (IE), Operations Research (OR), and Artificial Intelligence (AI) as well as the underlying principles in most commercial software development, tried to achieve an ideal scheduling system by focusing on the scheduling process itself. The modeling techniques applied thereby result in a simplification of the original problem – and a over-complex partial model of the mathematical scheduling problem – and thus have a tendency to create and maintain a model world. The solving an organizational problem was thereby reduced to solving a mathematical model. This situation produces a „theory-practice gap" [King (1976)] in shop floor control research which has been observed for several years [McKay et al. (1988)].

3.1 SIMPLIFICATION OF REALITY: ON THE QUALITY OF MODELS USED

The majority of scheduling approaches developed in the past decades is concerned with individual aspects of production. At the core, the approaches attempted to describe production in the sense of a quantitative, mathematical model as a sum of functions, while slack and security factors served to compensate for the model's imprecision. Here the implicit underlying assumption was that production is a mechanistic system, and its sociotechnical character [Pasmore (1988)] was ignored. The goal of approaches working according to the deterministic principle is to predict the behavior of the production system and to apply this knowledge to control.

In the context of technological advance – since the mid-1970s given its main thrust by rapid progress in computer science – the attempt was to better the insufficient precision by means of increasing refinement. The catchwords in recent years have been 'neural nets', 'fuzzy sets', 'genetic algorithms', 'simulated annealing', 'real time logistics' or 'multiple resource planning'.

Still attempts to gain a hold on uncertainty by means of increasingly precise mathematical models have not led to success in practice. As a result of insufficient means for problem solving, on the shop floor individual practices to complement the specified, formal control system where developed. These practices take on the form of 'the routine of the exception' in many companies, every day. The ultimate reason for this development was that the complexity of the fundamental problem exceeded the precision of the models supplied. In most cases, models could not adequately capture the dynamics of production and ended up – with high precision to be sure – limping behind real events. At the same time, the effort required to capture the data needed to reproduce events in such precise models increases to an unrealizable degree and is economically not feasible. The models utilized themselves become so complicated and non-transparent that they very soon overtax the user. The user can no longer interpret the model intuitively and is in no position to judge what data, when and with what degree of precision must be entered into the system. The user experiences the model as constraining, he or she can no longer react in a flexible manner as used to.

In practice, precise and deterministic models can be utilized sensibly only in those specific cases where quasi-deterministic system behavior can be assumed and the user's decision making process is of no importance. This would be the case, for example, with the process industry with its high demands for security of the processes and storage of resources, with highly automated, autonomous manufacturing systems or with continuous, highly automated mass production of semiconductors in clean room facilities.

3.2 GENERATING KNOWLEDGE: ON THE USE OF MODELS

The second major drawback of most scheduling research can be seen in the role of models. In much research, the goal of building a model is to be able to derive an optimal solution within the model. This results in a predominance of the model itself, while the transformation back to reality is often omitted or not even possible. This is readily observed in the great number of 'assumptions' that traditionally accompany many research papers. As [Pinendo (1995)] states, „it is not clear how all this knowledge [gained through mathematical models] can be applied to scheduling problems in the real world", since „real-world scheduling problems usually are very different from the mathematical models studied by researchers in academia.“

What is lacking is the link to reality, an examination of the question as to what models are used for, and a methodology to transfer results back into the real world. As [Reisman & Xu (1992)] put it in an article on knowledge growth in the management sciences, „much of the institutional infrastructure, e.g., the graduate programs, the professional societies and especially the landmark journals have become inbred. They concentrate on research based on established paradigms, work which is essentially logic-deductive rather than grounded in reality.“ Even worse is [Anthony’s (1965)] comment: „Although the usual definition of operations research as ‘What operations researchers do’ is probably intended to be facetious, there is much truth in it.“ One might be tempted to admit that this seems to be the truth in a vast part of modeling research for production systems design even today.

4 KNOWLEDGE GENERATION IN MODELLING: TOWARDS AN APPLICATION ORIENTED PERSPECTIVE

In an application-oriented approach, modeling can be seen as a means of generating knowledge about a system itself. That knowledge may then be utilized to determine possible and adequate changes to the system itself. Accordingly, it is not the model or the generation of a specific solution *(state)* within the model which is of concern, but rather the *process* of modeling itself as means of knowledge generation (Figure 1). A model „becomes a guide to the ways in which the system can be improved, [... rather than ...] a working tool for decision making in the system as it exists at the moment“ [Burbidge (1978)]. It is within this perspective that modeling methods gain relevance again as means of generating ‘understanding’.

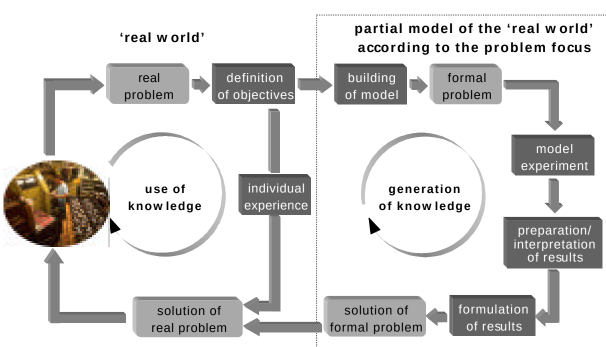

Fig. 1 Model based approach to problem solving [Wiendahl (1996)].

It is important to emphasize that the model-based approach will always result in a partial model of the ‘real world’ and thus only can provide a partial solution. It is this circumstance which makes it impossible to create the ‘perfect’ framework for research. Multiple views and individual experiences, i.e., a thorough grounding in reality, are necessary in order to reach a holistic solution. Thus, the present volume presents different views to allow for more than one perspective.

5 KNOWLEDGE FOR INDUSTRIAL USE

To examine the process of knowledge generation during modeling one needs to understand the areas of application in which models are utilized and the types of knowledge generated.

5.1 AREAS OF APPLICATION

In a first step, it seems necessary to determine the tasks for which models are used and can be used in practice. They thereby largely relate to a systems life-cycle:

Situation assessment:

– *situation analysis* and: modeling techniques can be used to describe a situation,
– building up *strategic concepts* to assess and verify basic objectives and visions to solve a problem.

System assessment:

– *system analysis* to understand the function and behavior of a system and its subsystems,
– definition of *systems requirements*, i.e., which problems should and could be solved in what extend.

System design and implementation:

– determination of measures and final *system specification* as baseline for implementation,
– *implementation* of the new system and compliance testing.

Systems operations:

– during *operations and maintenance* models are utilized as formal description of the system and its behavior,
– for *improvement* models provide a foundation to derive further measure and define their impact,
– finally, models allow a proper *shut-down* of the system.

For all areas one can distinguish between individual models, describing a certain AS-IS situation of an existing problem, individual models, describing a TO-BE situation for an existing problem, and reference models, describing a BEST-

PRACTICE situation for an imaginary situation related to a distinguished set of problems.

5.2 MODES OF KNOWLEDGE GENERATED DURING MODELING

In all areas models should result in knowledge. Here several modes can be distinguished. Among them are the following:

- models provide a formal solution for a problem,
- models provide a formal description of system behavior (e.g., FMEA),
- models facilitate knowledge on systems behavior (interrelation of system, elements and environment),
- models provide knowledge on critical factors and events and alternative scenarios for problem solving,
- models facilitate collective knowledge throughout a collective design process (e.g., through discussion, workshops, scenario techniques).

6 MODELLING METHODOLOGY FOR INDUDUSTRIAL USE

Based on the previous examinations, one can see, that a modeling methodology suited for industrial practice has to be embedded in a overall framework combining techniques for partial models and levels of observation and expertise, as well as framework for use.

6.1 PARTIAL MODELS

As a single modeling technology only can provide a partial view of the overall object, the models have to be considered partial models. Usually it is possible to define a set of constraints describing the task for which a partial model is suitable. Several partial models together allow a more comprehensive view of the overall object/problem. A specific partial model can be related to another through transformation rules. It should always be kept in mind, that such a transformation is not always definite in a mathematical sense and that the combination of several partial models never will enable a total and complete view of an object. Also partial models – even though each is correct within itself – two partial models can be contradictionary.

6.2 LEVELS OF MODELING

As seen in Figure 1, partial models and the "real world" are related. In general, modeling techniques tend to address design experts. In reality several roles use models, e.g., users, management, systems engineers and system developers. Each of this group has a different background concerning knowledge and experience. Besides they vary in their relation to the "real world" and the model. Whereas users obviously are part of the "real world" their knowledge and expertise often is needed throughout the design process, thus linking model and "real world". As a result, it often is necessary to determine several levels of modeling even within a partial view. A user oriented modeling approach has to provide easy understanding and should be suited to be used in workshop sessions and during collective design processes. A developer's model first had should be definitive and should not cause any mix-ups. Figure 2 shows a 3-level approach to modeling of business processes.

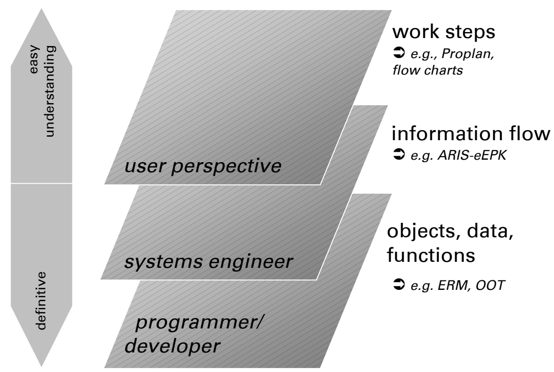

Fig. 2: Levels of modeling (example of business process modeling)

6.3 FRAMEWORK-FOR-USE

One of the major drawbacks of modeling methodologies is that the do not provide the necessary framework-for-use, thus resulting in the often heard "so what's next" indicating the fact, that a team of designers derived a beautiful model of a system but still not able to implement the first few steps towards a solution by means provided by the model. Within a framework-for-use a life-cycle model for modeling has to be added to the modeling methodology where each step is combined with the most suited modeling technique, quality requirements and critical success factors. Also it is necessary to name the appropriate roles of users, e.g., end-users or design experts, and the appropriate field of usage.

Quality gates within the framework need to ensure a minimum quality of the models themselves as well as the approach to modeling. To enable a great group of people to work with models, conventions about the modeling models as well as the object to be modeled have to be defined.

7 CRITICAL SUCCESS FACTORS

To ensure knowledge generation in practice several critical success factors apply that are not primarily related to a specific modeling technique but facilitate the ability to generate knowledge among users and designers. Such success factors are but are not limited as follows:

- Participation and support by the enterprise management,
- participation and trust of all users to allow the integration of experience and knowledge-in-use,
- definitive and understandable objectives for a project,
- a goal-oriented approach to problem solving putting results before methods,
- consideration of factors that can not be easily modeled,
- qualified training of everybody using models, from end-user, to management, to design experts,
- continuing reflection on the modeling process itself: Where were the success factors? Where were problems?

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