Library Based Modeling of Process Chains

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Abstract

This contribution gives an overview of the method Object-Oriented Modeling of Process Chains OMP. It is based on a library of process segments and allows an efficient configuration of complex process networks. The presented library represents a reference model, which is prepared to model the technical processing of customer oriented orders in a small series and one-of-a-kind production system.

After an introduction into the problem an object oriented concept will be discussed. The important features of OMP will be described. Finally, the influence of the level of detail in modeling will be investigated with the help of simulation.

Keywords

Object-oriented modeling method, reference model for processes, system of pre-determined times, modeling on different levels of detail, simulation.

1. INTRODUCTION

While on one hand, modeling means a simplification of the real system, on the other hand it is necessary to include all facts which are necessary to describe the dependencies of the system's entities. As a result, models of very complex systems are still complex themselves, especially if a good model quality is claimed. Thus, modeling means not only simplification and finding the main points of the system but as well requires the ability to handle the complexity of the model. In consequence it should be possible to choose any view on any level of detail which is included in a model representation. As a first step there is the task of creating a (detailed) model.

This paper focuses on the modeling of process networks, that represent the technical work-off of customers orders (see figure 1). The number of tasks in a process chain relates directly to the structure of the requested product, i.e. to the components and parts which have to be adapted to the special requirements.

Figure 1 Order processing in a small series or one-of-a-kind production.

Besides creating the process network, i.e. finding all tasks that are necessary to fulfill the order and setting them in a logical relation to each other, it is necessary to guess the task's efforts, especially its operations durations. Both, configuration of the process network and the qualified guess of durations will be supported by the method Object-Oriented Modeling of Process Chains (OMP).

2. OBJECT-ORIENTED MODELING OF PROCESS CHAINS (OMP)

OMP is a general method to configure complex processes based on a library. The latter includes a number of connected process segments and represents a reference model for processes. The concept of OMP is done under a strong object-oriented paradigm. Its main characteristics are abstraction, encapsulation, combination of data and behavior, inheritance and emphasis of object structure in contrast to procedure structure (Rumbaugh et al., 1991).

The objects of OMP are provided in figure 2. Its upper half includes all objects of the reference model, i.e. the objects for the process-library. The lower half of it includes all objects for the specific process-chains. They will be populated on basis of the reference processes. The symbol diagram (symbols following Rumbaugh, 1991 and Grobel, Kilger and Rude, 1992) shows all associations between the objects, e.g. the connection between *process* and its origin - the *ref-process*.

Modeling a specific order will be done by configuration of process-chains from the library. This task will be realized by the object's features. The procedure of modeling is specified by the complete specification of all objects, i.e. their attributes and their methods. While modeling, the objects call each other by their interfaces. As an example, the *detail* method of *process* is roughly described.

Legend:

object (class)

aggregation (part_of)

generalization (inheritance)/specialization (is_a)

association with multiplicity (in respect to instances)

ref

RAS

RMS

RLS

RPE

PAS

PLS

PPE

reference

reference-process_for_absolute_synchronization

reference-mark_for_synchronization

reference-process_for_local_synchronization

reference-process_for_parallelly_enlargement

absolute synchronization-process

local_synchronization-process

parallelly_enlargeable_process

Figure 2 Object classes in OMP.

A *ref-process-chain* and a time level (high, middel, low) are given as input. OMP provides possible chains, which could be choosen to detail the *process*: its origin

ref-process belongs to a *ref-process_group* and this may be detailed by a couple of *ref-process-chains* (see figure 2). The information which chains are allowed to detail an actual process is represented in the library. Thus, the method works context sensitive.

3. THE LIBRARY - A REFERENCE MODEL FOR ORDER PROCESSING

As shown OMP is based on a library. Its population includes process segments and knowledge of their configuration possibilities. The reference model encloses process chains for the technical processing of customer oriented orders in a small series or one-of-a-kind production system for goods.

A process dictionary is worked out as an elementary basis. Its ref-processes belong to the 32 ref-process-chains of the library LIB. Some of them for example represent the procedure of designing a component C or part P. Modeling a complex process-chain means specifying the customer variable part of a product structure. Table 1 shows an extract of the library. The grey marked ref-processes

Table 1 LIB-C: an extract of the library of process chains.

<i>Processes in Process-chains</i>	<i>H</i>	<i>M</i>	<i>L</i>	<i>ref-process-group</i>
<i>LIB-C</i>		R		
determining principle variant for C	30	30	30	
choosing solution principle for C	90	60	30	
determining DWS	90	60	30	
defining claims for adaptable sub-design-working spaces	120	60	30	
defining interfaces for the SDW	240	120	60	
determining purchasing parts	360	240	120	
designing a component	R	R	R	C-SOL, C-ALT, C-REC-SOL, C-REC-ALT;
designing a part	1050	780	285	P-ALT, P-SOL; DWS-ALT;
designing alternative DWS	R	R	R	
integrating moduls in DWS	360	180	30	
checking conformity	660	360	210	CONF_CHECK;
choosing alternative	120	60	30	
...	..	..	..	

Legend: ALT	(design) alternative
DWS	design-working-space
H, M, L	plan time high, middle, low
R	recursive structure is possible; plan time will be dependent from the component structure
REC	Recursion
SDW	sub-design-working-space
SOL	(design) solution

are detailable - also by alternative chains. The latter ones are fixed by the ref-process-group. There exist as well ref-process-chains which can be detailed recursively (REC), because the process-chain structure occurs similar to the recursive product structure (a component includes again components). Basically, each process has three plan times. Thus, a synthetical determination of planning times goes along with the configuration procedure of a special order.

4. MODELING ON DIFFERENT LEVELS OF DETAIL - INVESTIGATION WITH SIMULATION -

With regards to the level of detail there are two aspects. The first one refers to the level of detail which should be modeled. The second one considers the level of detail which should be used for an application.

OMP allows a very efficient modeling, even if the level of detail is very high. Nevertheless, the developed library includes ref-process-chains for a rough modeling as well. It allows to stop the detailed configuration procedure at any level. Then, specifying the tasks for a component simply include functions instead of processes, e.g. rough designing, detail designing and operations planning. A function includes the tasks of all sub-components and parts which are included with the actual component. The single tasks, e.g. operations planning for part 4717 and for part 0814, can no longer be handled separately. Subsequently, the process orientation will be lost and replaced by a function oriented modeling. A parallel view of the tasks will become impossible as well as a realization of simultaneous engineering. An aggregated process only can be assigned to one organizational unit and an organizational distortion may occur. In addition, it becomes difficult to guess the plan time for a complex task or function.

As a first result it can be summarized that a high level of modeling brings advantages if there exists a method which allows an efficient modeling procedure. The idea is not to reduce the complexity but to give support to handle it with regards to modeling.

The second aspect refers to the application of a process-chain model. There exist a lot of topics. One could be to plan a suitable organizational structure (Zülch and Grobel, 1992; Grobel 1993). Then, the level of detail should be high, because the tasks should be assigned separately and under several aspects to the different organizational units. Only detailed process-chains enable to model a product or process oriented organization in contrast to a functional one.

Another application refers to resources coordination or order control. This means a dynamical processing or simulation of modeled process-chains. As an example an order with the adaption of 2 components is modeled. Each of them contains 1 sub-component and 2 respectively 3 parts. In addition also the design of alternatives is considered and modeled. To investigate the influence of the level of detail a model of the same thing, the customer order, was created on four different ways: (a) with OMP and use of the full specification of the product structure; (b) with OMP and selecting a more aggregated level of detail but with information of the complete specification; that is coming up from (a); (c) with

OMP and the same level of detail as (b) but with chains for rough modeling and therefore, without full information; that is direct specification from the top to a certain specification of the product structure; (d) using (a) and aggregating its processes with respect to the given organizational structure; organization oriented modelling.

A good impression of the different modeling results is depicted in figure 3. It shows how the aggregation of the processes reduces the possibilities of realizing a parallel processing. The models (b) and (c) in relation to (a) aggregate the product structure. The sub-components are no longer broken down. Here begins the transition to a function oriented modeling. For example, the operations plans of the first sub-component's 3 parts can no longer worked out separately. Case (d) is fully aggregated with respect to the organizational structure. The organizational structure consists of 9 departments and is the same for all four process-chain models. Function oriented modeling in this regard means modeling with respect to the given organizational structure. In figure 3, all tasks of stability calculation are done for all parts in a single department (see vertically framed processes). The processes just left to it in (b) and (c) can be done in two different departments: One creates operations plans for rotary parts the other one for cubic parts.

Aggregation can be done under several aspects, e.g. product structure oriented or with respect to a given organizational structure. For dynamical handling and simulation the latter one is useful and mostly necessary. Why that...?

... it is because of a problem with the full detailed process plan. It provides too much freedom for dynamical processing. A simulation program tries processing as parallel as possible (see figure 4). There is no restriction or dynamical rule to solve the problem. Defining rules would bring simulation more and more to a determined processing. This would be the end of simulation.

Processing an order means changing the view from the product structure to the resources. This makes it useful to build packages of the process-chain's tasks which can be made in direct sequence (or parallelly) at one department. The problem is how to aggregate the tasks. The criterion may not only depend on the product structure. There is no hint how large a package of tasks should be. Thus, a method for useful aggregation remains as an open point.

The four ways of modeling lead to different system loads: (a), (b) and (d) have the same total load. They all are modeled with full information by the detailed structure from (a), i.e. a synthetic modeling with pre-determined durations is practiced.

An optical impression of the orderprocessing, done with the simulation program FEMOS (Grobel, 1992) is illustrated in figure 4. It is obvious that a higher level of detail goes along with more parallelly processing.

A real and valid processing is positioned somewhere in between (a) and (d). The process chain from type (a) allows to process any degree of parallelity and sequency. The remaining problem is the dynamic rule how to control resources and orders.

The level of detail may influence directly and massively absolute characteristics and even twice the goal accomplishments.

Figure 3 Modeled process chains for the same order

	evaluation period	evaluation period	evaluation period
department assembl. plan. calculation stability calc. operat. plan. • rotary operat. plan. • cubic design • standard design • complex			<p>(a)</p> <p>detailed process chains result in a highly parallel processing of the orders</p> <p>(b)</p> <p>process chains with a medium level of detail result in a moderate parallel processing of the orders</p> <p>(c)</p> <p>departmental oriented process chains result in large packages of tasks</p>

5. SUMMARY AND OUTLOOK

OMP allows a truly process or task oriented modeling of even complex processes. As the example has shown configuring a process e.g. for a component encloses nearly all tasks which are in connection with it. In contrast, function oriented modeling means an aggregation of tasks, mostly with respect to the organizational structure.

One of the major advantages of OMP is its context sensitive support for modeling. Thus, it enables a very efficient configuration procedure and provides a representation which includes several levels of detail with respect to the product structure. It supports as well a synthetic determination of plan times with predicted durations of tasks for higher aggregated processes.

The level of detail influences the modeling result and as well the dynamic order processing heavily. The rules for dynamic processing and simulation have to consider this influence. To assure predictability of system's behavior some more investigations are necessary. Simulation systems of today should be improved with respect to a valid dynamic processing of complex process chains.

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