GENERATIVE PLANNING IN A DET ENVIRONMENT

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Knowledge based methods in the domain of process and factory planning could lead to substantial savings for products with a high number of variants and production facilities. Although knowledge based approaches are already state of the art in the engineering and data management of complex products, these methods have not yet been applied to the planning of processes and production facilities so far. The extension of knowledge based methods to the domain of process and factory planning could lead to substantial savings for products with a high number of variants and production facilities. The objective of this paper is to demonstrate the state of the art in process planning with special focus on a possible integration with factory planning. Based on the literature review and the requirements of modeling data for the domain of process and resource planning, a methodology is derived and a prototypical solution based on commercially available software is demonstrated. The result is a knowledge based planning method for products, processes and the necessary production facilities.

1. INTRODUCTION

The situation of production enterprises is characterized by shortened innovation cycles, a rapidly rising number of variants as well as an accelerated technological progress. In those increasingly satisfied buyer's markets, the customers demand shorter delivery times, have high requirements regarding quality and technical functionality of the products and expect favorable prices. The cost and time pressure resulting from this, force the enterprises to develop new solutions (Dombrowski, 1996). For this purpose it is necessary to increase in particular the efficiency of the conventional planning processes. However organizational changes will not be sufficient enough. Therefore new methods have to be established for production and factory planning.

In the next section the term DET will be defined and substantial components of this concept are introduced. Since the emphasis of this work is on assembly planning, the next section discusses the requirements of software systems and their present shortcomings. Based on this the necessity of an optimized planning procedure is derived. Finally this article presents a realization methodology for an integrated knowledge-based assembly planning for high-variant products.

2. STATE OF THE ART

2.1 Digital Enterprise Technology (DET)

DET is a fairly new concept in academia and industry that has caught a lot of interest in the last couple of years. It is defined as “The collection of systems and methods for the digital modeling of the global product development and realization process, in the context of lifecycle management” (Maropoulos, 2002).

The system providers UGS (eManufacturing Server – eM-Server) and DELMIA (Integrated Process Database – IPD) are the two market leaders in this segment (Köth, 2003). Both software systems are based on one central relational data base. Additional tools such as process planning or ergonomics simulation are linked to the central database. Thereby the use of a consistent data model can be ensured across the entire product development process. Thus distributed working in the enterprise network with always current data is possible. Figure 1 presents schematically the sequential use of possible DET tools. The emphasis of this work is on the range of process planning for assembly. Therefore the following sections particularly deal with these tools.

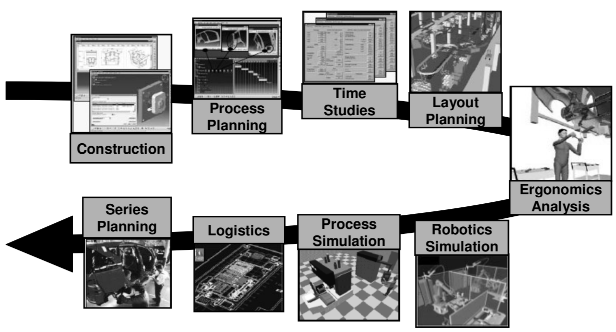


Figure 1 - Tools in the context of DET (Bley, 2004)

2.2 Assembly Planning Systems

The available software solutions for assembly planning of the above mentioned system providers are based on a systematic introduced by Jonas (2000) and Klauke (2002). As basis for the implementation of process planning, information from the domain of products, processes and resources have to be joined logically in a data model and illustrated in a semantically correct connection. Klauke (2002) clarifies in her publication the connection between the three entities (fig. 2).

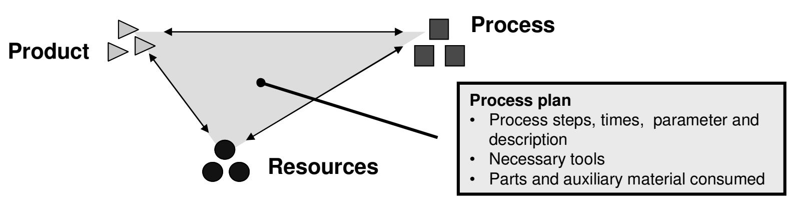


Figure 2 - Basic information for process planning (Klauke, 2002)

The elements product, process and resources represent the information of a work plan, in which the process steps with the necessary resources and products/parts are contained. The connecting lines between the individual elements represent dependences and illustrate in each case problems, which are to be considered in the context of production planning. On the basis of a linked storage the attached product and resources information can be made available over the inquiry of the processes.

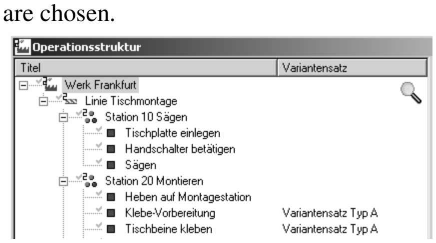
The class “product” specified in fig. 2 contains on the one hand the structure of a product, which can be illustrated for example over different modules. On the other hand it defines the characteristics of the objects e. g. the cost or the weight of components and higher-level information like tolerances. The structural configuration of the variants and/or alternatives is implemented by an association between individual parts and components. All assembly procedures, which will directly or indirectly contribute to the assembly progress, are administered by the class “processes”. Just as the product, assembly procedures are illustrated hierarchically in different levels of detail. The structure of these processes is provided similarly to the product structure through a one to one relationship. Apart from the hierarchical arrangement on different levels additionally temporal relationships (sequentially, parallel, alternatively) between processes are to be considered, in order to provide a consistent planning. The assembly progression is documented by the characteristics "predecessors" and "successors". In the class “resources” the assembly plants and their components are administered. For example the description of an assembly line or cycles of provisioning are contained. The structure of the class is comparable with that of the product. It exists likewise a hierarchical structure, in which tooling and/or organizational units are represented by an identification number and an appropriate variant set.

The data models presented by Jonas (2000) and Klauke (2002) are the theoretical basis for comprehensive computer assistance. The illustration of planning contents is very time consuming due to the various classes and linkages. Particularly the variant management is supported only insufficiently by the available software systems. This circumstance is described in detail in the following section.

3. DESCRIPTION OF THE PROBLEM

In the currently available systems for assembly planning it is only possible to model a maximal structure and apply different filters to select different objects. This approach can be compared to a maximal process plan, in which certain process steps or machines are omitted, if certain filter conditions are not met. This concept only works for a limited number of variants and simple relationships between objects. The following section describes this problem based on the example of a table assembly with two different product variants (type A and type B).

Compared to type B additional process steps are necessary for the production of type A as shown in fig. 4. In order to consider this in the planning process, different variant filters can be attributed to the processes. Only if a relevant variant is selected these processes are chosen.



= Resource
= Process

Figure 4 - Process structure in a process planning tool

Planning a specific variant, the corresponding filter is selected and all elements that are part of other filters are omitted for this specific planning result. In this example step 2 and 3 at station 20 are only valid for type A as shown in fig. 4, therefore they are removed for type B as depicted in the following fig. 5.

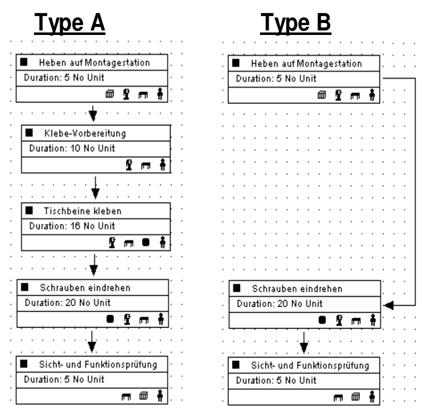


Figure 5 - Process structures for type A and B as a result of filtering

According to Walter (2002) there are hardly any differences regarding version and variant management between both major system providers. It is demonstrated in a study on digital enterprise technologies that the fulfillment of these functionalities is only realized on a moderate level. A major cause for this is a lack of methodical support for the representation of knowledge by a procedurally programmed solution algorithm as it is the state of the art in current systems. Using a system based on a knowledge-based planning methodology, the functionality can be increased substantially, particularly in regard to the variant management.

4. KNOWLEDGE BASES SYSTEMS – RESEARCH OBJECTIVE

Knowledge-based planning is based on the generative principle. Herein influence parameters create the required result with the help of deposited knowledge. The suitability for daily use could be proven for variant management in PDM systems and for the generation of work plans with CAPP systems.

Knowledge-based systems with a rule-based knowledge representation have a long tradition in the scientific research of process planning systems (Zäh & Rudolf, 2005). The results of this work were have not been transferred into DET systems with a central data management yet. This is caused by the fact that the exclusive use of rules for the representation of knowledge is not sufficient to illustrate complex knowledge relations. Therefore further representation forms have to be implemented.

According to Puppe (1991) there is a dependency amongst knowledge applications and suitable concepts (fig. 6). He distinguishes between the areas of diagnostics, design and simulation. Considering that process planning is the fundamental mapping between the domains of products, processes and resources it is very similar to the design process, mapping customer needs, functional requirements and design parameters (Harutunian, 1996). Therefore the same basic concepts should be applicable to the domains of design and process planning. Consequently, the methodology for process planning should be based on the concepts of rules, object-oriented representation and constraints. The relevant representation forms for the range of process planning are subsequently described in detail. The methodology should support a multiplicity of the presented representation forms.

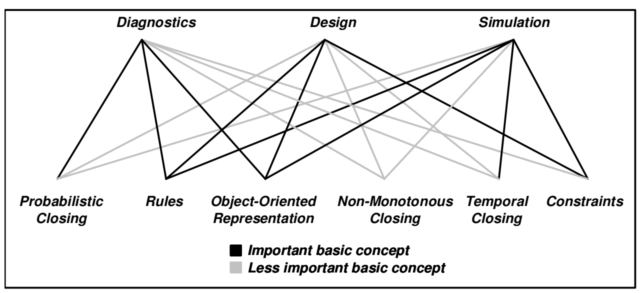


Figure 6 - Different concepts for knowledge applications (Puppe, 1991)

4.1 Rule-based representation

Rules are the most common form of knowledge representation in expert systems. They consist of a precondition and an action. The precondition describes in each case, when the rule may be used and the associated action is executed. Actions can be divided into two classes (Görz, 1995):

- Implications or deductions that affiliate the validity of a statement (e.g. “If A, then apply B").
- Actions that change a condition (e.g. “If A, then carry out B).

4.2 Object-based representation

Object-based representation is known to be a declarative system for describing, organizing and processing large amounts of knowledge. A first semantical order of the stored knowledge would be reached, if all statements about an object are combined into a frame (Puppe, 1991). The characteristics and behaviour of an object are held within a frame in different subjects, so called slots. Further frames with the same slots are produced by instantiation, thus representing the abstract object by a concrete instance, from a class frame. The structure of a frame is illustrated in fig. 7

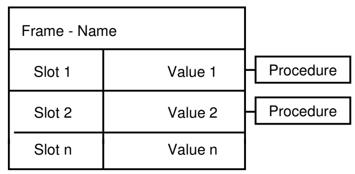


Figure 7 - Structure of a frame (Kurbel, 1992)

4.3 Constraints-based representation

Relations between variables can be represented by constraints. Constraints are particularly suitable for the representation of boundary conditions, which the solution of the problem has to fulfill in any case. Thereby a concrete problem solving is not specified. The goal is to find a solution by considering all relevant constraints (Puppe, 1991). In contrast to rules, which represent arranged connections, they express non-directional connections, which can be usually solved for each variable (fig. 8).

Example for rules

A => B „If A then apply B“

No statement from the validity of B can be deduced on the validity of A

Example for constraints

$U = R \cdot I$

If two variables are known, the third variable can be determined

Figure 8 - Difference between rules and constraints

5. PROTOYPICAL IMPLEMENTATION

In order to demonstrate the efficiency of a knowledge-based system an assembly planning system, which illustrates tasks of planning of a DET-tool, was implemented in an object-oriented development environment. Günter (1999) has compared different development systems available on the market. Among other things a comparison of the different methods of knowledge representation being used by the individual systems was made. Due to the circumstances stated in the last section the development system camos.Develop is particularly suitable for the described purpose.

The emphasis of the development activity was to realize an automated generation of process plans for different product variants. The information about the product as well as the necessary processes and resources were already formally illustrated in a conventional assembly planning system. This basic information has to be provided to the camos.Develop system by a suitable and efficient procedure. Data has to be exported from the assembly planning system into an XML document. Afterwards this file is mapped to an XML data structure, which can be interpreted by camos.Develop. During this process the existing semantic links between the individual entities had to be preserved. This was achieved by the help of the integration software Microsoft BizTalk Server 2004.

In this first stage of development of the system, advantages could be determined in relation to the existing commercial planning systems apart from the simple and clear handling for different variants. For example assembly times per work station must no longer be deposited manually in the network. They were automatically generated due to the deposited program logic with selection of a specific variant. Furthermore the developed system allows a very flexible illustration of the variant structures. In conventional planning systems a very complex maximum structure has to be implemented with variant-specific processes, which can be filtered by corresponding variant codes (fig. 10).

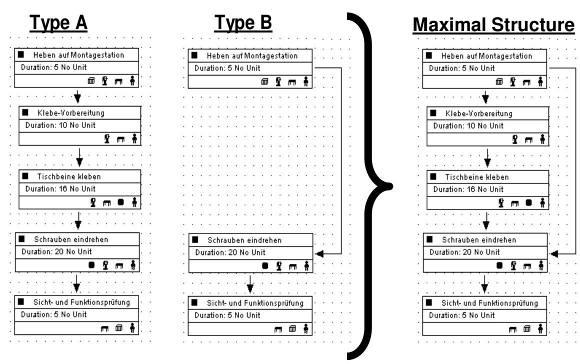


Figure 10 - Maximal structure of processes in a DET-tool

Thereby the development effort increases substantially with a larger number of different variants and specific orders. The sequence of child elements can be generated in a knowledge-based system with the use of an index at run-time. This means that objects and their links do not have to be specified multiple times. With the help of an index the correct sequence, which is valid for the respective variant, can be generated using a rule.

6. CONCLUSION

The aim of this work is to show the enormous potential of generative planning functionality to be included in DET systems especially in the area of variant planning. To do so the state of the art in digital enterprise technology for assembling planning was shown. In the currently available systems for assembly planning it is only possible to model a maximal structure. The fact that different filters had to be applied to select different objects leads to the deployment of a new planning methodology. With this methodology planning content can be transferred and used in the developed assembly planning systems to support the planning task, especially for complex planning projects. This approach allows a semi-automated generation of plans for similar scenarios, instead of a manual one, which is based on copying and modifying existing projects. The realized advantages should be implemented in commercially available DET systems, which have their own advantages such as a high level of integration into simulation tools or factory CAD systems.

7. REFERENCES

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