2

FEATURE DRIVEN ASSOCIATIVE PART AND MACHINING PROCESS MODELS

László Horváth
Budapest Polytechnic
John von Neumann Faculty of Informatics
lhorvath@zeus.banki.hu

Imre J. Rudas
Budapest Polytechnic
John von Neumann Faculty of Informatics
rudas@zeus.banki.hu

János F. Bitó
Budapest Polytechnic
John von Neumann Faculty of Informatics
jbito@zeus.banki.hu

Aniko Szakal
Budapest Polytechnic
szakal@bmf.hu

This paper describes a research for associative integration of part and part manufacturing modeling. In order to gain associative models, the authors analyzed effects of changes of part models on manufacturing process models. Also they analyzed how part manufacturing and production constrain part design. The applied modeling is based on generic Petri net representation of manufacturing models that facilitates handling of process variants by using of the same process model. The modeling assumes unified solid model with topology controlled identification of surfaces and reorderable form feature based part model. The paper is organized as follows. Firstly basic concepts and objectives of the integrated modeling research are introduced. Following this, relationships between part and part manufacturing processes are detailed. Next handling of effects of part model changes and implementation of the proposed modeling are discussed. Finally, contribution to enhancement of capabilities of present day CAD/CAM is concluded.

V. Mařík et al. (eds.), *Knowledge and Technology Integration in Production and Services*

1. INTRODUCTION

Continuous development of products can be realized only by the application of advanced modeling techniques as form features as building elements of part models, variational geometry and constraints. Traditional lack of manufacturing process modeling for this purpose is the main obstacle to integrated application of flexible design, manufacturing planning and manufacturing technologies.

Changes in a part model are often deteriorate part manufacturability [6]. Correct analysis of manufacturability is a difficult and complex task because manufacturing and production aspects are to be handled together with economical and financing considerations. Effects of a change of a model on manufacturing are hard to be foreseen. Quick assessment of this effect and quick repeated evaluation of the manufacturing process are main objectives of this research. As preliminaries of this research, a generic manufacturing process model [1], an integration of the manufacturing process model in a Virtual Manufacturing (VM) environment [3] and an application of knowledge based methods in manufacturing process modeling [2] have been proposed by the authors. The main contribution of this paper is integrating a manufacturing process modeling methodology with form feature based part modeling by the using of relationship and constraint definitions. Constraints posed by the manufacturing process model restrict the range of allowed modifications of the part model. Generic manufacturing process modeling has been conceptualized taking into consideration recent achievements in generic product modeling [7].

The paper is organized as follows. Firstly basic concepts and objectives of the integrated modeling research are introduced. Following this, relationships between part and part manufacturing processes are detailed. Next handling of effects of part model changes and implementation of the proposed modeling are discussed. Finally, contribution to enhancement of capabilities of present day CAD/CAM is concluded.

2. OBJECTIVES AND CONCEPTS

Customer demanded continuous improvement and variant creation of products are challenges in early 21st century. Quick response of product design for customer demands is a basic requirement that also assumes quick response of manufacturing process planning, production planning, production control and production. While flexible product design and flexible production resources are available, present day manufacturing process planning technology can not cope with these requirements. Prevailing process for physical shape creation is still machining.

Figure 1 summarizes the causes and effect of main changes in part models. Changes in actual orders including changes in customer demanded product features demand changes in design of parts. Other part design changes are decided during continuous product development. The above-mentioned changes of part models affect the related manufacturing processes. Scheduled and unforeseen changes the job shop level as breakdowns, damages and shortages of production equipment, devices and tooling, including electronic control units and devices affect manufacturing processes. Minor changes of part models are often solutions for serious shop floor problems. Using associativity driven relationships between models, modification of a parameter of a model entity initiates a chain of modifications of other parameters of other model entities. Results of earlier decisions are protected by constraint definitions. Relationships of the constrained parameter with other model entity parameters propagate the constraint.

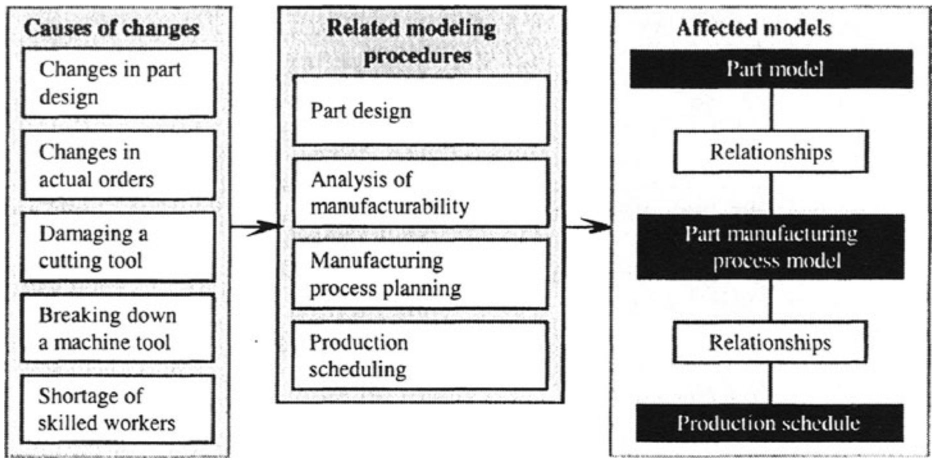

Figure 1 - Engineering activities in changing environment

Let's consider part manufacturing. Manufacturing engineers still use traditional process structure and process elements. This is why the authors considered the same structure and process elements for their modeling as applied by conventional manual planning of part manufacturing processes (Figure 2).

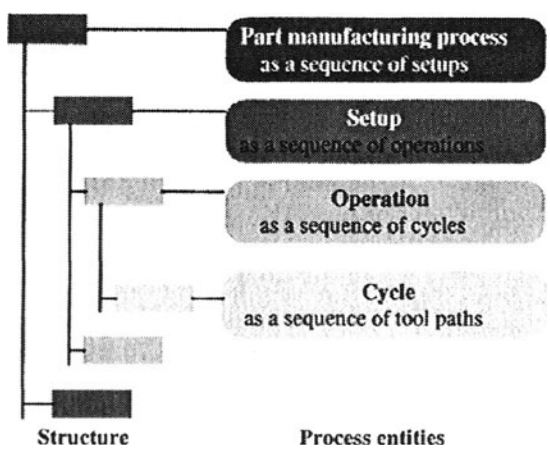

Figure 2 – Entities in the structure of part manufacturing process

The Authors earlier investigated application of Petri net as representation in the demanded generic, multiple leveled manufacturing process model. As a continuation of that research, the authors are working on an integrated modeling approach and methodology where relationships govern and constraints control mutual modification of models as required in flexible engineering and production systems. Figure 3 shows the structure of the proposed generic manufacturing process model in accordance with the structure of part manufacturing process (Figure 2). More details about the model can be read in [2]. Petri nets are well proved for solving large number of problems in the manufacturing engineering [4]. Various concepts are applied for handling the variant nature of manufacturing process [5].

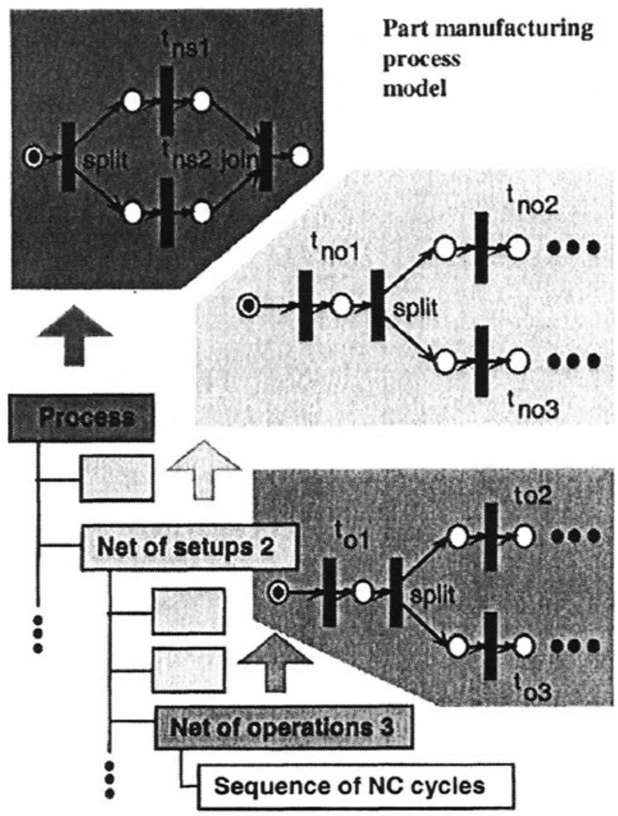

Figure 3 - The part manufacturing process model

3. ASSOCIATIVITY DEFINITIONS BY RELATIONSHIPS

Feature based part model is created by a series of modifications of a basic shape with form features. Sequence of these modifications is recorded in the part model. If a shape modification effect of the form features is the same as of the related machining operations then manufacturing process model entities can be mapped to part model entities directly.

The sequence of shape modifications can be reordered for machining process planning reasons. As a result, two sequences of shape modifications are created, representing construction and manufacturing shape aspects. Reordering of shape modifications is available in feature driven modeling systems. Using relationships between part and part manufacturing process models, manufacturing process model entities can be related to part model entities (Figure 4a). The sequence of shape modifications is reorderable according to the requirements of operation sequences within setups. The result is a tree of shape modifications in which a branch describes a manufacturing task for a setup. A form feature is mapped to an operation or a cycle. Geometric entities are accessed through topological entities in boundary representations.

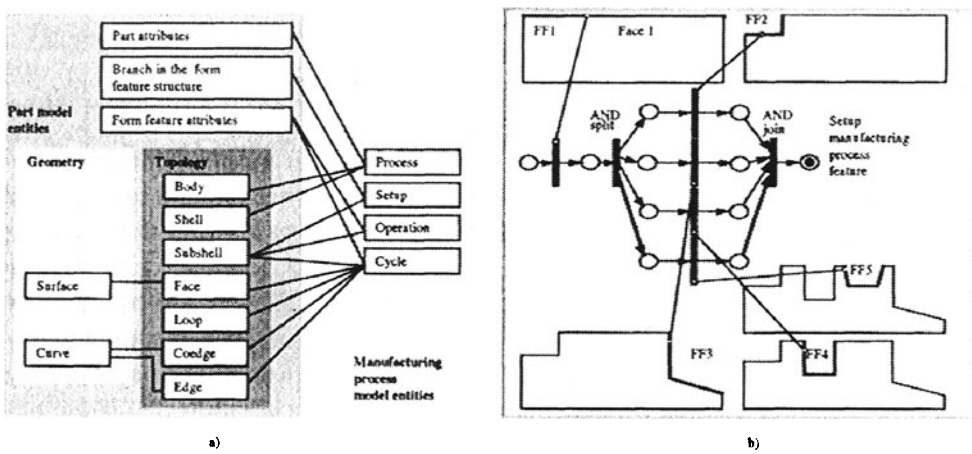

Figure 4 - Possible relationships between part and manufacturing process model entities

Figure 4b illustrates modeling of a setup when shape modifications during creation of the part model are the same as shape modifications of the part during manufacturing. A setup consists of a sequence of operations. A transition represents a machining operation for a shape modification. Machining of *Face 1* is represented by a transition then all shape modifications are mapped to appropriate transitions in the manufacturing process model. Repeated execution of a Petri net takes into consideration machining of the newly created form features in the manufacturing process. If an operation is proved to be suitable and available in the shop floor level, it gains an *in process* status. This method support handling of variants because omitted or suppressed form features will not be taken into account in the process model. Suppression, omitting or deleting a form feature results *out of process* status of the affected operation.

4. EFFECTS OF PART MODEL MODIFICATIONS

Changes in a part model are handled as follows. When an entity or one of its parameters is involved in the part model, this information is communicated with the appropriate manufacturing process model creating procedures immediately. Then these procedures react to the change and do as they can by processing the new model information. Using relationships (associativities) does this by between model entities or their attributes. Breaking of constraints is not allowed but revision of constraints can be initiated.

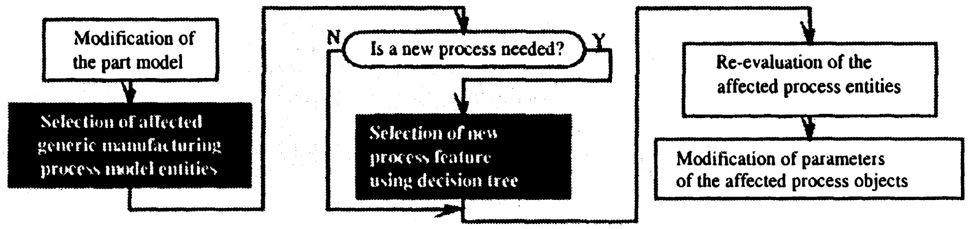

Figure 5 - Modification of the process

Any modification of a part model initiates analysis of its effect. Then modification the process model can take place (Figure 5) if necessary. The affected generic manufacturing process model entities are selected by using of relationships between part and process models. Needs for modifications are analyzed level by level within the manufacturing process model. If a new process is needed, its selection should be repeated. The new process is selected on the basis of modified part model attribute values by using of decision tree then evaluated in the way that is detailed in [3]. If an old process is to be modified then the affected process features are repeatedly evaluated and a new process variant is created. Evaluation of a process model entity includes checking the involved process objects for suitability and availability then execution of the Petri net. Sometimes a modification of the part model needs only repeated calculation some manufacturing process object attribute values as diameter or length of a cutting tool.

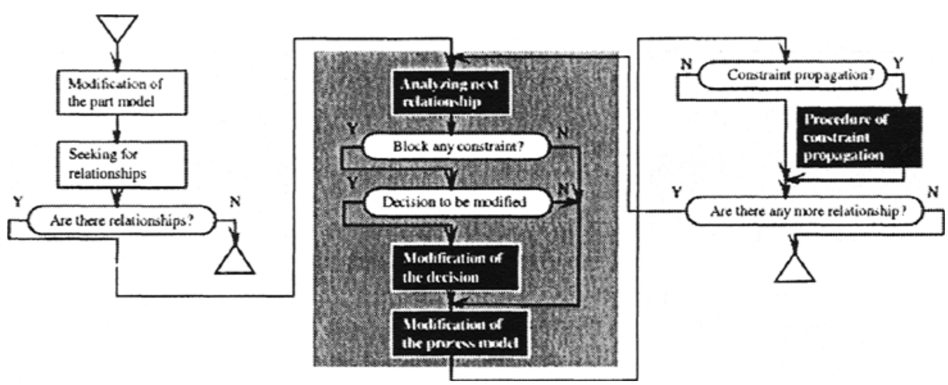

Figure 6 - The mechanism of manufacturing process modification

Effect of part modification is governed by relationships between part and manufacturing process models (Figure 6). If a relationship points to a constraint, it can be modified only by modification of the related decision by an authorized engineer. Reverse application of a relationship can be used for making proposal for part model modification. Modified constraints are propagated in the manufacturing process model.

Form feature dimensions in a part model often govern manufacturing process variants. A detail of a net of operations feature for a setup is represented in Figure 7. An OR split and join pair handles three variants of operations. The decision on variant is done at the place P_d using IF-THEN-ELSE rules. These rules are attached to the place P_d. Rules define relationships between part and process models. Modification of dimension h_2 can reverse an additive type feature to a subtractive type feature in the part model (Figure 7). The resulted shape contains a slot that requires an additional slot milling operation (*branch=V2*). Substantial increase in length l_1 results exceeding the upper limit of the end milling (ULEM), an additional face milling operation (*branch=V3*) is to be included. After firing of the transition that represents the OR split tokens at the places in the two unnecessary branches are made inactive before firing of the first transition on the selected branch.

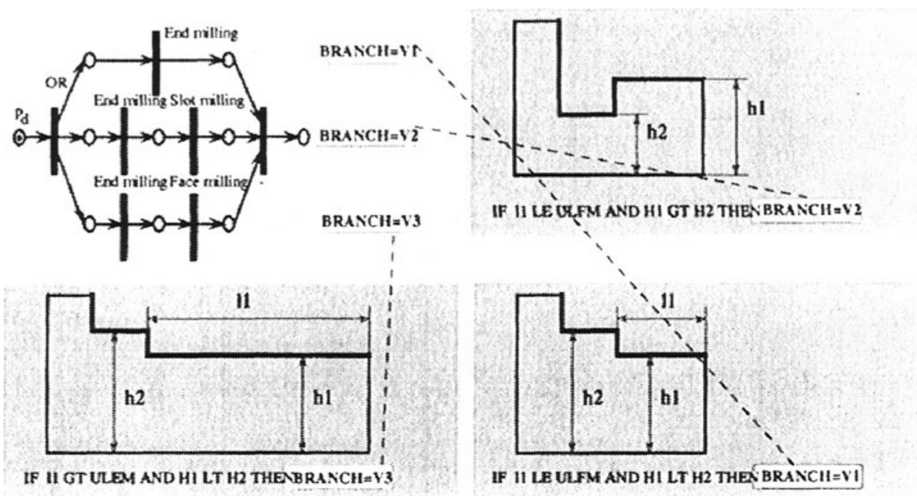

Figure 7 - Feature dimension driven creation of manufacturing process variants

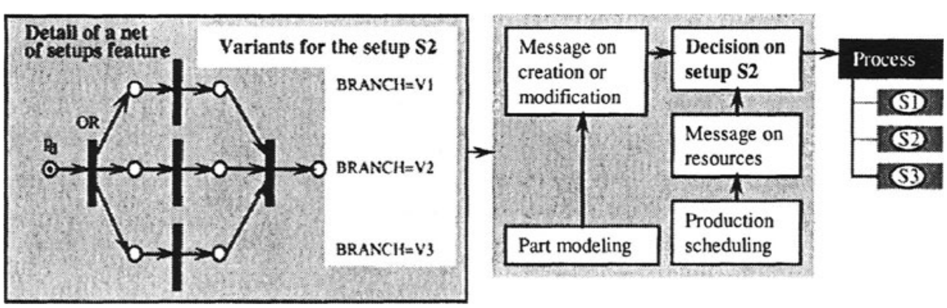

Figure 8 - Decision on setup variants

A detail of a generic net of setups manufacturing process feature on the Figure 8 shows that three setup variants are offered to choose from. A variant is selected as a solution on the basis of groups of form features that can be manufactured in a single clamping position on a single machine tool.

5. CONCLUSIONS

A feature relationship driven integration of manufacturing process model and part model has been proposed in this paper by the authors. They intend to fill the conventionally existing gap between these models. Generic process model entities are proposed that are full associative with form feature based part models. An actual process variant is created by evaluation of generic manufacturing process model entities. This evaluation is automatically repeated as an effect of part model feature changes. The authors proposed application of their earlier developed Petri net based manufacturing process model as generic description of part manufacturing processes. Integration of the proposed manufacturing process model by using of relationships can be used for communication part model modification information with a generic process modeling system and initiating repeated evaluation of the process model in order to creating a modified manufacturing process. The proposed method is intended as a contribution to research on integrated product information modeling. A higher level of integration of product and manufacturing engineering has been introduced in this paper.

6. ACKNOWLEDGMENTS

The authors gratefully acknowledge the grant provided by the OTKA Fund for Research of the Hungarian Government. Project numbers are T026090 and T037304.

7. REFERENCES

1. Horváth, L., Rudas, I. J.: Emerging Intelligent Technologies in Computer Aided Engineering, *Journal of Advanced Computational Intelligence*, Vol 4, No. 4 2000, pp. 268-278

2 Horváth, L., Rudas, I. J.: Modeling of Manufacturing Processes Using Petri Net Representation. *Engineering Applications of Artificial Intelligence.* ,Vol. 10, No. 3. pp. 243-255, 1997

3 Horvath, L., Rudas, I. J.: Evaluation of Petri Net Process Model Representation as a Tool of Virtual Manufacturing, *Proceedings of the 1998 IEEE SMC International Conference,* San Diego,California, USA, 1998, Volume 1, pp. 178-183

4 Desrochers, A. A., Al-Jaar, R. Y.: *Applications of Petri Nets in Manufacturing Systems*, IEEE PRESS, New York, 1995

5 Kruth, J. P., Detand, J: A CAPP System for Non-linear Process Plans, *Annals of the CIRP*, 1992/1. pp. 489-492

6 Shah, J. J., Mantyla, M., Shah, J. J.: Parametric and Feature-Based Cad/Cam: Concepts, Techniques, and Applications, John Wiley & Sons;1995

7 Männistö, T., Peltonen, H., Martio, A., Sulonen, R.: Modelling generic product structures in STEP, Computer-aided Design (30)14 (1998) pp. 1111-1118