UNIVERSITY OF ZIELONA GÓRA
Faculty of Management
and Faculty of Mechanical Engineering
In association with the Design Society

FOURTH INTERNATIONAL SEMINAR AND WORKSHOP
7th - 9th October 2004
Zielona Góra - Rydzyna
POLAND

Engineering Design in Integrated Product Development
Management of Design Complexity

# APPLICATION OF METAMODELS IN KNOWLEDGE BASES MODELLING OF DESIGNING PROCESS

**W. SKARKA**

Silesian University of Technology
Department of Mechanical Engineering
e-mail: wskarka@polsl.pl

**Keywords:** metamodelling, knowledge base, designing

**Abstract**: *Knowledge base is more and more commonly used as a way to aid designing process. In the presented method of constructing such bases structuralisation of particular knowledge domains is used. For structuralisation purposes ready made patterns can be applied, which are used in data base designing. Metamodel forms one of these patterns. The paper presents examples of metamodels' application for designing of data base contents. Metamodels and models examples for procedures of designing process and product structure have been shown. The usefulness of metamodels has been evaluated and comparison with other patterns of data modeling for this application has been made.*

## 1. INTRODUCTION

Designing process of machines and devices is getting more and more complex. Because of the multi aspects of that process it is necessary to have broader knowledge to solve designing problems and therefore knowledge bases are used in the designing process [4], [5], [6], [7], [8], [9]. In order to design the structure of such knowledge bases the patterns of data structure can be used. Metamodel is one of the patterns of data structure.

Metamodels due to their specific features are suitable as patterns for complex data structure [1]. In the presented example of knowledge base for modeling knowledge base resources in designing process metamodels have been used as patterns for a big range of data structure of informative system, for the model of the designing process itself or product structure.

Despite the fact that in structure creation from compound elements which reflect structural paradygm elements it is advised to use metamodel as a designing pattern, its usage is neither easy nor the form is obvious. Metamodel solves problems of structure extension and can also help with introducing changes in knowledge base structure, enabling addition of new structure elements without actual modification of its structure.

## 2. PATTERNS IN DATA MODELLING

One of the fundamental tasks in application designing, and in particular data base applications is to design proper structure of data. For that purpose so called designing patterns can be used, which form some general model of system data structure [1], [10].

Designing patterns have been introduced by specialists of object designing. It has been noticed that some aspects of creation of application project do not change and previous design can be used. Application of designing pattern facilitates higher flexibility and universality of the created data base system, which is especially favorable to a less experienced designer of informatics systems. He can take into consideration amendments and modifications of experienced informatics designers in a brief and simple way.

The following patterns can be differentiated [1]:

- Abstract pattern
- Analytic pattern
- Metamodel

## 2.1. Abstract patterns

Abstract pattern forms a pattern of classes and relations connecting them, creating general solution of a nonspecific problem. Notions of patterns do not correspond to notion of objects connected with given problems. This task must be solved by a designer on his own. The following patterns are included in that group:

- Single pattern – it is used in situations when some class can have only one instant within the base.
- Component pattern – describes the tree structure where all the objects realize some common interface. Such structures are applied in hierarchy representation e.g. to realize structures of whole-part type.
- Flyweight pattern – allows limiting system redundancy by means of management of co-shared elements. There is a division of dependant and independent data (normalization). Limitation of redundancy depends in creation of objects which include only dependant data and placing these data in separate container.

## 2.2. Analytic patterns

Analytic pattern forms physical objects generalized for a repeated usage. The degree of generalization is smaller than in the case of abstract pattern. The patterns include solutions commonly used in designing informatics systems of organization e.g. problems concerning organization, people, place, process and document:

- Party pattern – serves to model organization structure and people connected in relations (e.g. employment, responsibilities)
- Geographical pattern – allows modelling of a net of geographical areas exceeding the usual representation of addresses. It is used in geographical informative systems –GIS.
- Process pattern – is used for modelling continuous production processes based on the flow of materials and in particular those which cannot be divided into independent units (elements list cannot be differentiated).
- Document pattern – serves to model simple and structural documents and their users, aiding data searching in documents.

Metamodel – is model which is presented only by some authors [Graves]. It allows structure modeling of a given object by means of a set of component objects. It is possible to create general models of very complex relations between data.

Metamodels make it possible to avoid creation of complex models which are difficult to service, to understand or modify. It is probable to avoid expensive and time consuming changes during the system development. Metamodel is sometimes classified as abstract model. Due to the important role it plays in creating the model of knowledge base structure it will be discussed separately and more detailed.

## 2.3. Metamodels

For modeling knowledge resources in designing process metamodel was chosen as a designing pattern of a great scope of information system, including product structure model (Fig. 5.) or the designing process itself (Fig. 2.) [2], [7], [8]. When creating structures from component elements which reflect elements of structural paradigm it is advised to use metamodel as designing pattern [1]. Application of metamodel in information structure modeling connected with designing process has appeared in recent works on that topic [7], [8], [9], [10]. Metamodel solves problem of structure increase and is capable of solving the problem of introducing changes in base structure which enable easy modification of the structure of data base without real modification of data base structure. Additional data is fed into the metamodel structure in a way that it becomes a part of already available class. The figures below present two different approaches to designing process modeling.

Fig.2. shows metamodel of designing process whereas Fig. 3. and 4. present model for the same designing process. Metamodel of designing process is a description of structural paradigm of designing procedure. The structure of procedure is based on four main elements :

- *DescriptionItem* - forms general, formal description of procedure (notion, problem description etc.).
- *Inputs* – include elements describing input data necessary for procedure, dividing data into obligatory and recommended ones.
- *Outputs* – include elements describing output data and allowing interpretation of the result.
- *Strategy* - strategy of problem solving – contains elements describing operation strategy while solving a given designing problem. Methods are distinguished which allow knowledge capturing from completely different methods of solution of the problem. They can be alternative methods or sequence e.g. introductory or exact ones. Each method is described in details by means of a set of actions.

It should be pointed out that metamodel includes data description of one procedure as opposed to designing process which is a set of procedures in a

form of a net of procedures which can be used in any sequence. The path of procedures' order depends first of all on the result of previous procedures and also on the subjective assessment of a designer. Such a net of procedures is formed by connection of procedure by means of data described by *PreviousProcedure* and *NextProcedure* element (Fig. 1.). In this way it is possible to create a net of any degree of complexity, develop a net by adding new designing procedures as well as supplement procedures with new methods of solving problems and all that without changing metamodel structure of designing procedure. The model of the whole designing process is therefore, created while obtaining knowledge from designers and is a part of designing knowledge.

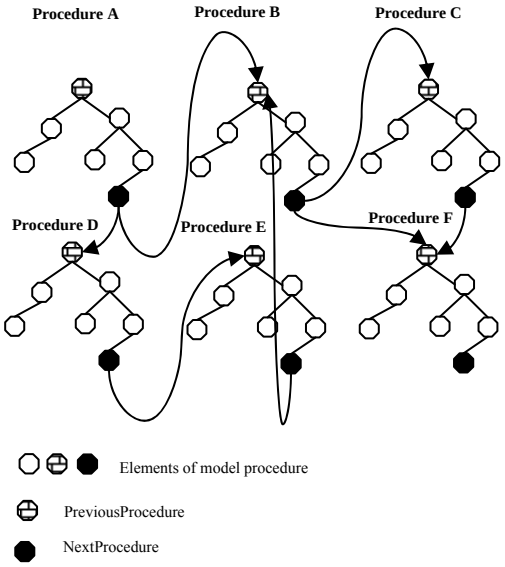


Fig. 1. *Net of procedures connected with PreviousProcedure NextProcedure elements*

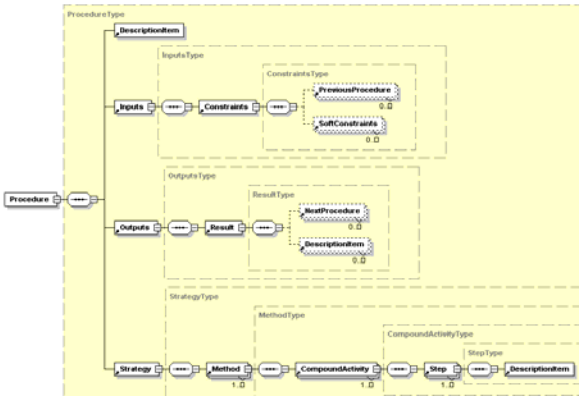

Fig. 2. *Metamodel of designing process (XML schema)*

It is not possible while using other design pattern of designing procedure, describing in details the elements of designing process (Fig. 3. and 4.) [3]. In this knowledge base model all the elements of designing process are defined thoroughly and semantically from the needs analysis and definition of a problem via initial design, and finally to technical documentation. Although only the root of a model structure was shown it can be immediately seen that this model has great degree of complexity. At the same time a designer of any branch may have some doubts about the structure of designing process, lack of some designing phases or redundancy of others since each field has its own uniqueness and each designer his own code of practice. Such a model is too complicated and at the same time does not meet requirements of different designing fields. Modification of designing process may require the necessity of change of the structure of process model and it can be difficult to perform. At the same time such a model does not allow dynamic choice of path of designing procedures. Getting rid of these disadvantages means additional expansion of a model and its complexity which would make the service of a model more difficult or even discourage from its usage. Metamodel lacks all these disadvantages – it is simple, and the model itself is built on the designing site and can be changed and developed without any limits.

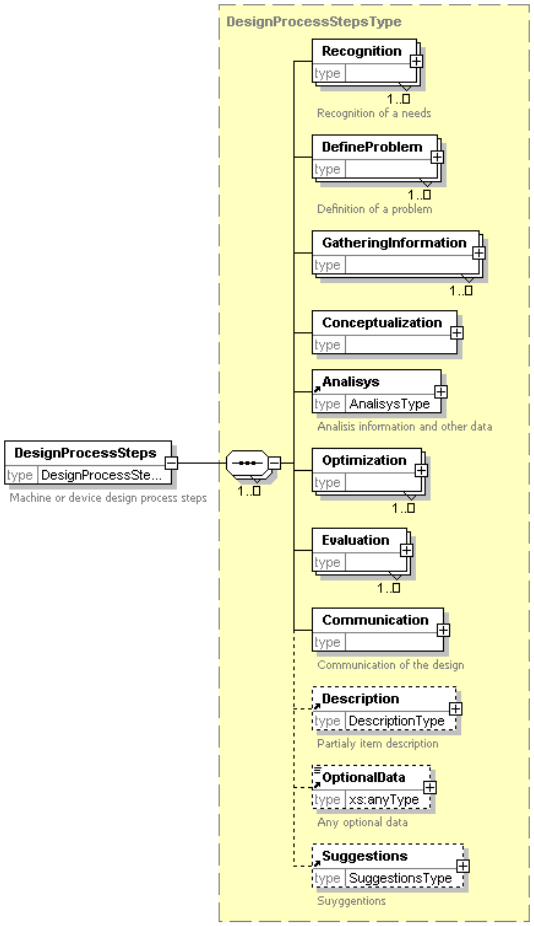


Fig. 3. *Root of a model tree of designing process (XML schema) [3]*

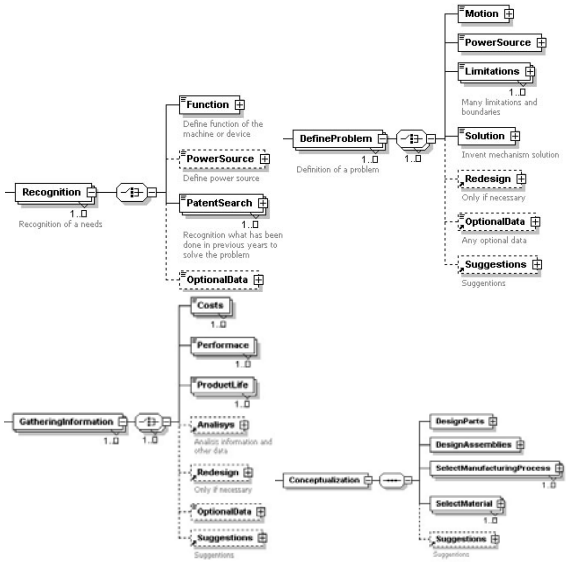


Fig. 4. *Lower branches of a model of designing process on Fig. 3.– recognition of needs, defining a problem, gathering information, conceptualization [3]*

Metamodel of a product structure forms other example of metamodel used in knowledge base (Fig. 5.).

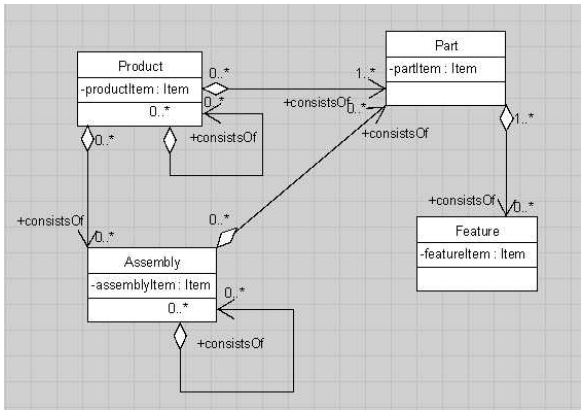


Fig. 5. *Product structure metamodel*

## 3. CONCLUSIONS

Metamodels can be successfully used for modeling the structure of knowledge base of a designing process. By means of application of metamodels in knowledge base creation for designing process it is avoided to create complex models which are difficult to service. It is of great importance for models of the highest degree of generalization. For base structure elements which have not been presented in this paper it is recommended to use partly standardized data models. As examples one can give personal address data where a model should be compatible with the accepted requirements e.g. xNAL, xNL, xAL [11]. The usage of these informative standards by means of modular structures facilitates the creation of the whole model and allows easy updating.

## References

[1] Graves M.: *XML Database designing. Handbook.*(in polish) Gliwice: Helion 2002

[2] Kołodziejczyk D. & Skarka W.: *Native XML resources as knowledge bases in intelligent computer aided design.* Artifical Intelligence Methods, AI-METH , Gliwice 2002.

[3] Kostempski M.: *XML in Integrated Data Exchange Environments.* (in Polish) Department of Machine Design Fundamentals, Silesian University of Technology, Gliwice 2003

[4] O'Leary, D.: *Using AI in Knowledge Management. Knowledge Bases and Ontologies.* IEEE Intelligent Systems May/June 1998. 34-39

[5] Pokojski J.: *Intelligent integration process aiding to computer aided design of machines*, (in Polish) WNT, Warszawa 2000.

[6] Pokojski J.: *Towards personalised software in machine design*. Computer assisted mechanics and engineering sciences, vol.9.No. 1. 2002

[7] Skarka W.: *Collecting and Sharing Designers' Knowledge in Collaborative Environment.* Proceedings of 10th ISPE International Conference on Concurrent Engineering: Research and Applications. Advanced Design, Production and Management Systems. 26-30 July 2003, Madeira, Portugal. A.A. Balkema Publishers Lisse 2003

[8] Skarka W.: *Integration of product lifecycle knowledge in CAD*. e-Work and e-Business in Architecture, Engineering and Construction. ECPPM 2002 Portoż /Slovenia/ 7-11 September 2002.

[9] Stokes M (Editor): *Managing Engineering Knowledge.* Professional Engineering Publishing Limited London and Bury St Edmunds, UK 2001

[10] Werner, H. & Weber, C.. *Ligo – an Object-Oriented Modeling for Integrated Product Development.* Integrated Product Development Workshop. Magdeburg. 1998

[11] Website: *Oasis Technical Committees – CIQ: XML Standards for Global Customer Information Management* http://www.oasis-open.org/committees/ciq/ciq.html