https://doi.org/10.26552/com.C.2000.1.4-9

kamUNikácie
COMMUNICATIONS

Janusz Pobożniak *

MODELOVANIE VÝROBKU PRE ÚČELY CAD/CAM INTEGRÁCIE

PRODUCT MODELLING FOR CAD/CAPP INTEGRATION

Základnou podmienkou dosiahnutia plnej automatizácie je integrácia CAD/CAPP/CAM systémov. Dôležitou časťou vo vývoji počítačom podporovaných systémov v predvýrobných etapách je modelovanie výrobku. Najrozšírenejšou modelovacou metódou je prvkové modelovanie. Spomenutá metóda je veľmi sľubná, pretože môže do značnej miery využiť geometrický model vytvorený v CA systéme. Zlepšenie výmeny informácií o výrobkoch medzi CA systémami pracujúcimi v prostredí CE, môže zvýšiť stupeň počítačovej podpory v automatizácií. V článku je prezentovaná architektúra navrhnutého CA systému, spĺňajúceho určené požiadavky.

The key condition for achieving the full automation is the integration of CAD/CAPP/CAM systems. The important element in the development of computer aided production preparation system is product modelling. The most widely known modelling method is feature based modelling. The mentioned method is very promising because it can extensively use the geometric model created in CA system. The enhancement of product information exchange between systems working in CE environment can increase the level of computer automation. The proposed system architecture fulfilling the requirements is presented in the article.

Introduction

The widely used tools for computer aided production preparation are CAD/CAPP/CAM systems (Computer Aided Design/ Computer Aided Process Planning/ Computer Aided Manufacturing). The key condition for achieving the full automation is the integration of these systems, they must exchange information between themselves. In other case, to perform operations automatically some information must be entered, and this process of information input is tedious and often a source of errors. For example, in non- integrated CAD/CAPP systems environment, all information about the product must be once again fed to CAPP system although they have been already modeled in a CAD system. Similarly, in a case of non- integrated CAPP and CAM systems, to program a machine tool the user must enter all geometric information about the product (Fig. 1).

Fig. 1 Non- integrated CAD/CAPP/CAM systems: "Islands of automation"

The key element in the development of computer aided production preparation system is product modeling. It is of fundamental importance in Concurrent Engineering where teams of experts (designers, process planners, etc.) together develop a new product. In modern implementation of CE methodology teams are replaced by computer systems which must be capable of exchanging information, especially information about the product which is in the focus of realized activities (Fig. 2).

The most widely known modeling methods are syntactic pattern description, problem- oriented languages, declarative languages, GT coding, feature based modeling. The method mentioned last is very promising because it can extensively use the geometric model created in CAD system. In this method features can be interactively defined. The user designs the use of the already prepared set of features, or features can be extracted automatically. There are also several methods of feature recognition including pattern recognition, decomposition approach, logic approach and AAG graph methods [4].

However it should be noted that many solutions to the problem of product modeling does not fulfill the requirement of concurrent engineering environment because they are narrowly focused on some aspects, as for example on feature recognition. The system for product modeling working in CE environment should have the product model fulfilling the requirement of all systems using it, it should read the geometric model directly from CAD system and must be capable of bi-directional exchange of the information between particular systems.

The enhancement of product information exchange between systems working in CE environment can increase the level of computer automation. The proposed system architecture fulfills the requirements mentioned above.

* **Ing. Janusz Pobożniak M.Sc.**
Cracow University of Technology, Institute of Production Engineering and Automation, Al. Jana Pawla II 37, 31-864 Cracow, Poland,
Tel.: +48-12-648 05 55 ext. 3284, Fax: +48-12-648 20 10, E-mail: pobozniak@mech.pk.edu.pl

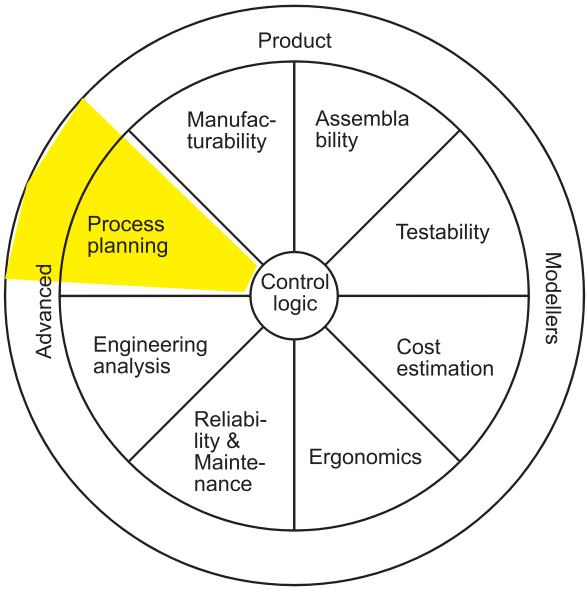

Fig. 2 The use of product model in Concurrent Engineering environment [Joshi94]

1. System architecture

The system for product modeling should feature:
- user- friendly interface and modeling approach
- access to the information on different level of abstraction,
- possibility for modeling all product- related information,
- bi-directional exchange of information between system working in CE environment,
- mechanisms for information exchange with other systems for product modeling.

Fig. 3 presents the architecture of system fulfilling the requirements mentioned above. The presentation of its most important modules and methods of implementation follows.

2a. Feature oriented product model

The product is described by the graph:

$$G = < F, R >$$

where F - The set of features
R - The set of relations between features

Feature is any entity used in reasoning of design, engineering, and manufacturing [3]. Features have different abstraction levels. They can represent assemblies, subassemblies, workpieces, surface sets, and even low-level geometric entities. Assemblies are composed of subassemblies, subassemblies are composed of workpieces, the components of workpieces are simple and complex manufacturing features. Simple manufacturing feature consists of surfaces, edges, etc.

The example of simple manufacturing features are thorough slots, countersink holes, steps, etc. The simple feature can be grouped into complex features. The example of complex features are multi-staged holes or combination of pocket and slot. The features reflect the hierarchy of product structure (Fig. 4). Features are represented using the object-oriented approach. The object is a set of data, procedures for these data processing and mechanism for message (information) exchange. The use of object-oriented methodology enables to reflect the hierarchy among features and relations occurring between them.

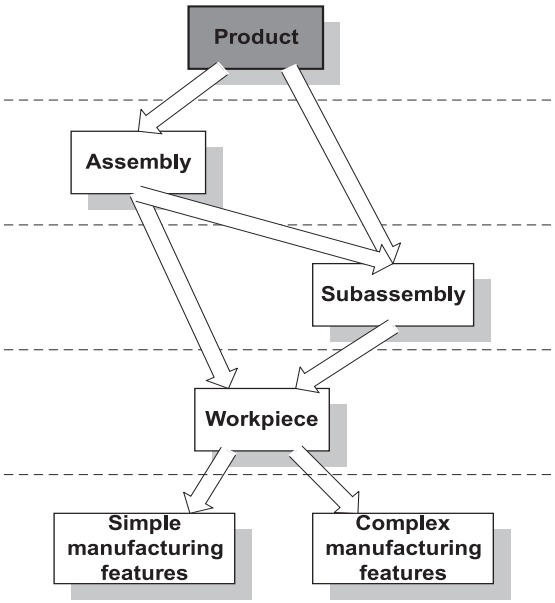

Fig. 4 The hierarchy of product structure

The Relation is a constraint imposed on a single feature (object), or constraint imposed on two or more features. Several types of relations can be distinguished, the most important from the process planning view are:
- tolerance relations (for example: parallelism, perpendicularity)
- assembly relations used to model assemblies (for example relations 'based_on' and 'fits' describing the relative positions of parts)
- relations between features describing the relative positions of features (for example 'perpendicular_to' and 'parallel_to')
- parametric relations in the form of algebraic equations (for example: 'maximum diameter < 60, 'dimension A + dimension B < dimension C)
- Functional relations of movement, force and localization.

The partial taxonomy of relations is presented in Fig. 5.

2b. Communication bus

The systems working in CE environment must exchange information, particularly information about the product being developed. The product model is an intermediate element between design and manufacturing, and it is also used to create different variants

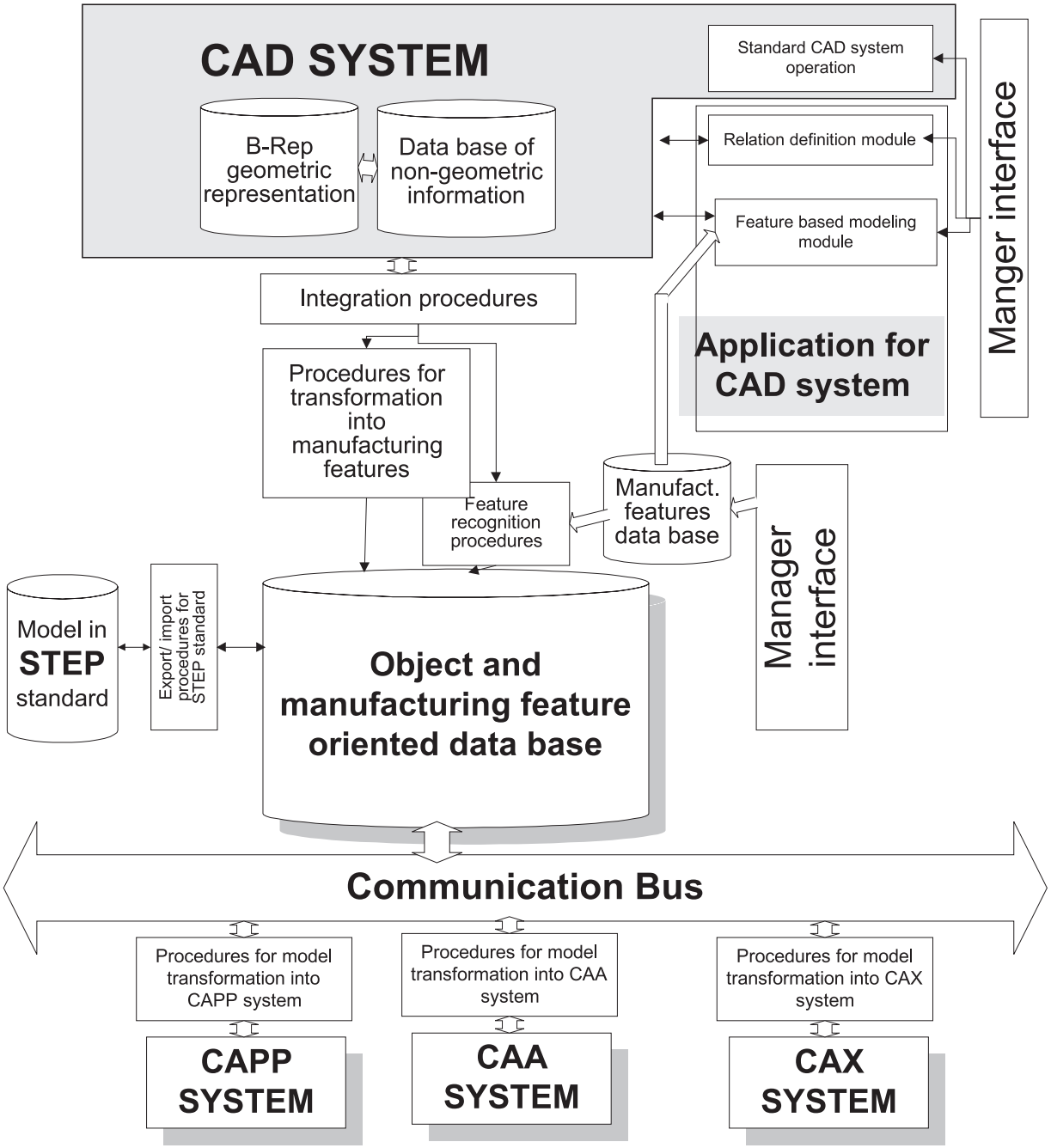

Fig. 3 The architecture of system for product modeling in CE environment

during its whole life-cycle. The example application using this model are Computer Aided Design (CAD), Computer Aided Process Planning (CAPP), Computer Aided Assembly (CAA) and Computer Aided Fixture Design (CAFD) systems. This is the reason why proper modeling and representation of product related information is a key element in CE environment development.

According to the recent research and experience gathered in industry, the product information is sent not only from CAD system to CAPP system, but the information must be also sent in a reverse direction, from CAPP system to CAD system [5]. Such feed-back information from the CAPP system will enable the designer to take adequate decisions related to material, machining accuracy, hole diameters, etc. Also the information about the

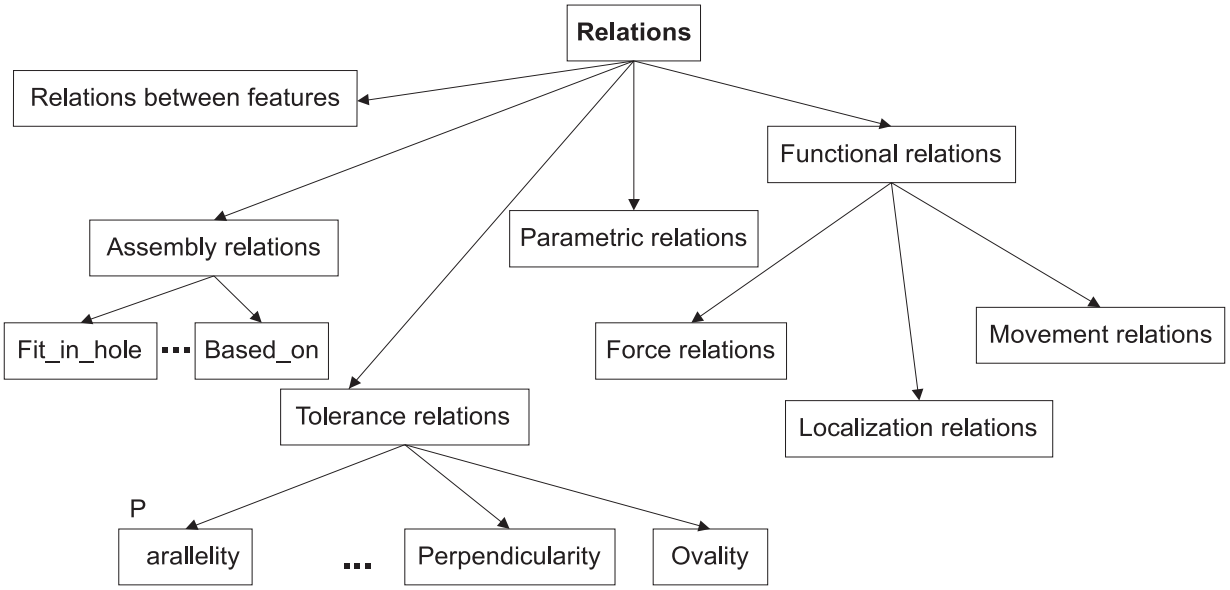

Fig. 5 The partial taxonomy of relations

costs of special features, special tools, and complex machining methods will help the designer to select most suitable design variant.

The exchange of information between a product modeling module and systems working in CE environment is done by means of messages which are sent thorough a communication bus.

The message has the following format:

```
MESSAGE(recipient, message_name, result,
(list of parameters))
```

where: `recipient` - the feature (object) to which the message is sent
`message_name` - the message identification
`result` - the result of message processing.

The messages are distributed in the feature tree (object tree) using the general message distributions techniques available in the object- oriented methodology.

One of the key development aspect are the means to implement the communication bus. The simplest solution, independent from the operating system is data exchange by text files. Such mechanism is used in the expert system Exsys Proffesional for the data exchange between Exsys and external programs. Beyond any doubt, the main advantages of this solution is the simplicity and the independence from the operating system. It is also possible to employ other more effective methods available in very popular nowadays windowed environments such as Windows 3.11, Windows 95 and Windows NT. For example OLE, DDE, or exchange through the Clipboard can be used. Despite the fact that these solutions are more difficult to implement, they secure greater throughput and allow for the use of more complex data-structure. In case of the distributed CE environment the messages are sent through the computer network.

2c. Commercial CAD system with application for non-geometric information modeling

A very important aspect influencing the modeling system functionality is the method of model creation. Two modeling methods can be distinguished [7]:

- process planning oriented methods
- methods using commercial CAD systems

Despite difficult implementation, methods using commercial CAD systems are gaining increasing popularity because they offer a full and unique geometric model, flexibility in the model creation, and CAD systems are widely used in industry.

Commercial CAD systems to be used must be customized. The reason is that non-geometric information such as tolerances, surface roughness, material treatment are stored in the form not suitable for processing by the computer software, especially by the expert systems. The non-geometric information is represented in drawing format (such as DWG, DXF, or IGS) in the same way as geometric information, using standard entities such as lines and texts. In the proposed solution the commercial CAD system is customized by the application running in its environment. This application attaches non-geometric information to the drawing entities, and it is also used to represent the relations used in the product model. The non-geometric information should be

interactively entered in a CAD system in a way not limiting the use of other system functionality. In the developed system, the

SolidEdge" from Intergraph is used, it employs the B-Rep (Boundary Representation) method.

2d. Procedures for manufacturing feature oriented product model creation

The task realized by the procedures for feature recognition, feature transformation and data integration is to convert the geometric model from CAD system, non-geometric data entered with the use of application for CAD system into the fully manufacturing feature oriented product model. The feature are recognized from the B-Rep representation using the logic approach [4].

2e. Manager interface

The possibility to use the user-defined feature is a very important factor influencing the design and process planning functionality and effectiveness [4, 21]. It is not possible to create the finite feature set meeting the needs of all products, or manufacturing systems. Even in the boundary of one company, modernization of production facilities or introduction of new products requires the feature set to be changed. It is obvious that not all features are known at the time of system implementation. Because of this, the product modeling system must be equipped with mechanism for feature set modification.

The users should not be allowed to modify features individually, the formal procedure should be followed. The changes should be implemented by the manager of the product modeling system on requests from the users. The modifications are done through the interface of the system manager.

2f. Export/ import procedures for STEP standard

The standardization is a key aspect influencing the cost and the time of product development. The product information must be exchanged between companies participating in the project. Very often the companies are using systems from different vendors. On the market are also available the catalogues of standard parts on the electronic means of storage.

There are several data exchange format available for drawing data exchange including IGES, DWG, DXF, WMF and ACIS. The main disadvantage of these formats is the fact the information is exchanged on the level of geometric entities such as lines, circles, surfaces, basis 3D solids and texts.

The most promising now is the new generation format called STEP (Standard for the Exchange Product model data, or PDES - Product Data Exchange Standard) developed by the International Organization for Standardization (ISO) as the means for product data exchange. The information is exchanged without any losses.

Because of these facts the product modeling system will be equipped with the import/export procedures for STEP standard.

3. RESULTS

The product modeling system architecture presented above features the following:

- use of commercial CAD system for geometry modeling and all its functionality being the source of the popularity of these drawing systems,
- exchange of information by means of messages without the need to know the structure of the product model database,
- exchange of information on the level of logic product representation, and not on the level of basic geometric entities and so the similarity to the natural way of communication between engineers,
- use of object oriented methodology simplifying both the understanding of the product model and its implementation during programming
- access to the information on different level of abstract
- the possibility for modification and development of system by manager on requests from users
- running on the network
- exchange of information with other product modeling systems equipped with STEP interface

Reviewed by: J. Peterka, R. Debnár

4. REFERENCES

[1] ACIS, Save file format manual, Spatial Technology, Inc., 1996
[2] BRADLEY, H. D., MAROPOULOS, P. G.: Concurrent Engineering support system for the assesment of manufacturing options at early design stages, AMPST'96 Conference, Bradford 1996
[3] CAM-I 90, Proceedings features symposium, CAM-I, report no. P-90-PM-02 ,Boston, 1990
[4] CHANG, T. C.: Expert process planning for manufacturing, Addison- Wesley Publishing Company, Inc. 1990
[5] ELMARAGHY, H., et i inni: Evolution and future perspectives of CAPP, Annals of the CIRP, Vol. 42/1/1993
[6] HERMAN A.H., LAWLEY M.L., LU, C.-Y., MATTOX, D.: An opportunistic Approach to process planning within Concurrent Engineering Enivronment, Annals of the CIRP, Vol. 42/1/1993
[7] ISO 10303- 11, Product Data Representation and Exchange. Part 1: Overwiew and fundamental principles
[8] ISO 10303- 11, Product Data Representation and Exchange. Part 11: The EXPRESS Language reference Manual
[9] KALTA, M., DAVIS, B. J.: Converting 80-character ASCII IGES sequential files into more conviniently accessible direct- access files, Int J Advanced Manufacturing Technologies, vol. 8, 1993

[10] KALTA, M., DAVIS, B. J.: Guidelines for building 2D CAD models of turned components in CAD-CAPP integration, Int J Advanced Manufacturing Technologies, vol. 8, 1993
[11] KARACALI, O., BELL, R.: "Concurrent design expert" application with "CAE" driven information model, MATADOR Conference, 1996
[12] KOCH, T.: Zarzadzanie jakoscia - czesc 3: Metody i techniki zapewnienia jakosci, Instytut Technologii Maszyn i Automatyzacji Politechniki Wroclawskiej
[13] LIU, T. H., FISCHER, W.: Developing feature- based manufacturing applications using PDES/STEP, Concurrent engineering: Research and Applications, vol 1, 1993
[14] POBOŻNIAK, J.: Przeglad metod modelowania przedmiotów, Seminarium "Systemy CAPP", Politechnika Krakowska 1996
[15] POBOŻNIAK J., Przeglad metod rozpoznawania cech, Seminarium Naukowe ITMiAP, Politechnika Krakowska 1997
[16] PRATT, M. J.: Synthesis of an optimal approach to form feature modelling, Proc. of the Int. Symposium on Advanced Geometric Modelling for Engineering Appliacations, Berlin 1989
[17] SANTOCHI, M., GIUSTI, F.: An approach to CAD-CAM integration: development of an interface for the Euclid, 1986
[18] SAMEK, A.: Projektowanie procesów technologicznych obróbki skrawaniem i montazu, Skrypt dla studentów wyzszych szkol technicznych, Krakow 1986
[19] SEMAKULA, M. E., SATSANG, A.: Application of PDES to CAD/CAPP integration, Computers in Industrial Engineering, vol. 18, No. 4, 1990
[20] TÖNSHOFF, H. K., AURICH, J. CH., BAUM, T., HAMELMANN, S.: A Workpiece model for CAD/CAPP applications, Production Engineering vol. I/2 (1994)
[21] TÖNSHOFF. H. K., AURICH, J. CH., BAUM, T.: Configurable feature- based CAD/CAPP System, Proceedings of the IFIP International Conference