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SOME PROBLEMS OF PRODUCT DATA MODELLING FOR CAD AND CAM SYSTEMS

Summary. The paper discusses the present state and current trends in the computerized modelling of product data. First, notions of the model and attributes classification are given, then a critic of the product data modelling based on purely geometric representation is formulated as this representation is inadequate for designer's needs.

Different points of view on the product model are discussed and the concept of "a feature" is introduced as a basic element of reasoning language in engineering. Applications of features and major hindernis in implementing them in CIM systems are discussed in the end of the paper.

1. Introduction

Models are used generally in engineering. They represent various aspects that originate from the "life cycle" of a product, beginning at the problem formulation up to the product liquidation. There is no one-to-one correspondence between a product and its model. There may be as many product models as are viewpoints of the people involved in the product design, manufacturing, testing, exploitation, servicing, etc. Eeach model contains a specific information relevant to specific needs or purpose. A model can be seen as the structurized set of attributes of an original object intended for representing a specific viewpoint on the original |1|. An attribute or a characteristic comprises a portion of information that characterizes the object in one ore more aspects. To build models of a machine or its part material form attributes of the structure form are used and among them there are primary constructional attributes which describe:

- configuration (topology),
- shape (geometry),
- size (magnitude),

- material,
- properties of surfaces,
- fits and tolerances.

These are called primary property attributes since they are properties of a real entity. There are also other, secondary properties like mass, strength, conductivity, etc. which may be regarded as resulting from the primary ones.

The behaviour of a machine or a part under external influence exhibits yet other attributes, which are called relational, becouse they are only observable in relation to outer systems. One of the typical relational attributes is reliability. Also producibility attributes belong to the relational ones. Figure 1 presents a hierarchy of the attributes.

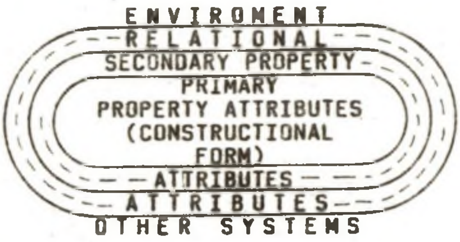

Fig.1. Categories of attributes in mechanical egineering [2]

Various product models reflect variety of attributes, not necessarily of one category.

2. Inadequacy of Contemporary Product Data Modelling Systems

The amount of information needed to develop and describe a product from its inception through production until its operation can be sizable, even for relatively simple products. To store and to retrive the information large amounts of resources are required. It has arisen serious problems of structuring, converting and integrating the product data between several applications, which has not yet been solved.

A major weak point today is lack of integration between the design, analysis, manufacturing, marketing, servicing and other activities related with the product. Current technology has created separated islands of computer aids within the sea of computer integrated manufacturing (CIM) issues. This makes the use of CAD/CAM in routine engineering work quite inconvenient. CIM requires the sharing of product information between functions and converting it from one representation to another, where the second representation is for a different application than the first.

The more, even in the limits of one kind function data there are many problems that have not been solved yet. For example, current CAD systems usually provide two-and three- dimensional engineering drawings representing a part or product by sets of points, lines, surfaces, and/or primitive volumes. This type of representation has several deficiences.

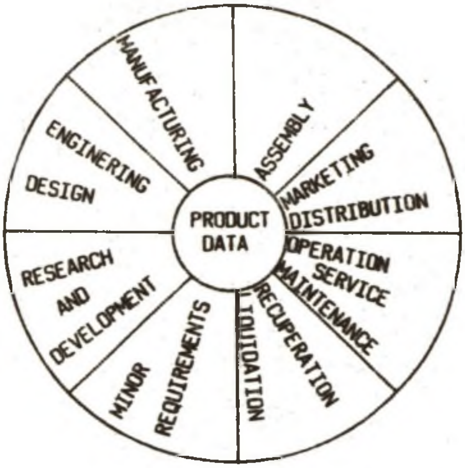

Fig.2. Sources of product data requirements

First, the designer does not think in terms of the low-level geometry, so he/she has to disrupt his conception into very primitive geometric entities.

Secondly, the modelling capabilities of the current CAD systems are centered around the geometric modellers. As consequence the user is forced to create detailed geometric information before physical and functional attributes are known.

This contrasts sharply with natural way of thinking of most designers who start with conceptual design rather than the detail, bottom, phase of design. Major improvements are needed to aid the activities pertaining to conceptual and embodiment design and to link them consistently in a computer system with the detail phase.

Third, the traditional CAD systems are not able to capture and manage functions intended by the designer for a part or product. Purely geometric representations are unable to provide the information necessary for reasoning about the nongeometric aspects of design. The designer's intentions can not be included in the representation of the in-progress design, The result is that the designer is never sure if he/her intent is preserved.

3. Nonuniqueness of the Model Interpretation

Computer integrated manufacturing (CIM) implies the integration of design with process planning and manufacturing, each of them requires different types of information. This stems from the different points of view that are associated with each of these engineering domains. This raises the question how to support the different viewpoints consistently.

The primary attributes describe geometry, topology and basic physical and/or chemical properties. Thus, a model of the primary property attributes defines a unique physical object. However, the designer, the process planner and the manufacturer, each of them, sees and interpretates the model differently because each of them associates a different engineering meaning to it. For example, Figure 3 illustrates two possible views of the same part, one from the designer´s viewpoint, who sees cylinder with the ribbed hole, and the other from a machinist´s who perceives it as a cylindrical block with volumes which need to be removed to from the grooves and steps. Therefore, the same part with its identical attributes can be viewed as being composed of different elements depending upon a particular engineering viewpoint. Since engineers reason rather with pieces of information that relate property attributes with a particular purpose, than with the attributes alone, so it is clear that modelling in terms of attributes does not meet the needs of CAD, CAM, and, more generally, of the whole mechanical engineering domain. Thus, a knew representation language is indispensable to make computer systems more suitable for engineering tasks. The words or primitives of this language are called features.

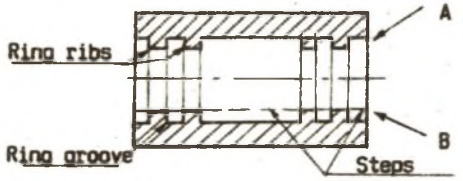

Fig.3.
Designer´s (A) and machinist´s (B) views of the same component

4. Features

4.1. Meaning of Features

The concept of "a feature" has been used implicitly in enginering design since a long time but it was explicitly expressed just a few years ago. According to [3], Pratt and Wilson were the first who introduced the concept of "designing by features" [4,5]. During the past several years, many researches have recognized features as a natural form of communication among designers, analysts, process planners and manufacturers [6,7,8,9]. Most of the research has been related to the machining process and has been constrained by existing CAD and solid modelling representations. This has led to the form features, such as bore and hole, which can be used by the mechanical designer for reasoning about the manufacturability and other characteristics of a part. Relatively less research has so far been conducted with regard to features related to other manufacturing processes [6]. To recognize and extract features of a designed part with its complete geometric representation poses a difficult process. Specific methods and algorithms have been described in literature how to identify features. Designers use features in a different way as a kind of high-level modelling primitives which can be thought of as the important structural elements of reasoning language during designing.

An example of the system for designing with features is shown in Fig.4. The features used by the designer are called design-with features and they are available in a library as shown. The designer builds a computer model of an artifact using the library of design-with features and a set of add, modify, and delete operations, which is available in another library. A monitor ensures that the designer´s requested and performed operations are allowable and understandable to the system. The primary representation of the design

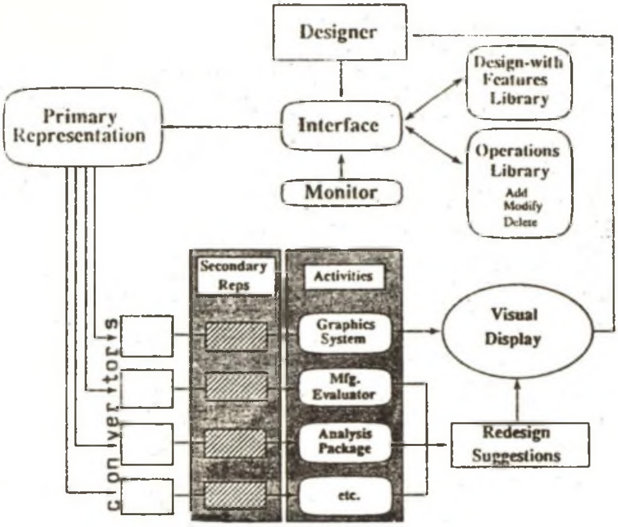

Fig.4. A design-with-features system [6]

is composed of design-with features. Subsequently it is converted into the secondary representations which are needed by their respective activities. These representations are used subsequently by the modules of the system to reason about the specific design characteristics. The system´s ability to construct the proper secondary representations is the key to a succesful implementation of a design-with features system. Since the secondary representation must be created from the user-created primary representation, the last is also influenced by the secondary representations. This imposes constraints on the design-with features. Moreover, because amount of the features and operations in the libraries must be finite, it constrains the designer. It is not certain, if the impact of these limitations will be acceptable by creative designers, and whether they can be reduced in the course of further research [7].

4.2. Feature Definition

Because features are viewpoint dependent and one can have multiple feature models for one part or assembly, there is no consensus on a precise definition of a feature. Most researches working in the area agree that a feature is an abstraction of lower-level design information to a high-level modelling primitive which encode engineering significance of the primary property attributes. Many definitions have been offered in the literature, some quite general, other more specific, for example:

"A feature is an entity used in reasoning about the design, engineering, or manufacturing of a product".

"A feature is a collection (set) of faces of a boundary model".

"Features are abstract entities that combine functionally related elements of a model".

"A feature is any geometric form or entity that is used in reasoning in one or more design or manufacturing activities".
"It is an entity with both form and function".
"It is a set of information related to a part's description. The description could be for design purposes, or manufacturing and inspection or even for administrative purposes".
"It is a model of the form and intent of some aspect of a design which is of direct interest in a CIM viewpoint".
"Features are generic shapes with which engineers associate certain properties or attributes and knowledge useful in reasoning about the product".
"A feature is a partial form or a product characteristic that is considered as a unit and that has a semantic meaning in design, process planning, manufacture, cost estimation or other engineering disciplines" |9|.

Thus, features are not limited to being geometric entities nor are they limited only to design and manufacturing, although most of the research to date has been on geometric features for design and manufacturing.

4.3. Feature Implementation

Features technology is a fast developing field; the basic concepts and methodologies are still evolving. High level features offer considerable advantages over existing CAD systems, which provide purely geometrical and topological representations. But still, many problems remain to be solved. Among these three deserve particular attention:

- feature origination,
- feature interaction,
- feature conversion.

The first concerns the question, what feature types should be like. How many of them should be predefined and how many will be left free to be created by the designer? What level of complexity should they have? Whose viewpoint should be accepted as the basic for definitions of primary features (designer's or manufacturer's or, perhaps, user's?). It is possible to incorporate more than one viewpoint in one feature?.

The second problem arises when two or more feature intersect so that this influences either the form or semantics of a feature. The part may even be physically realizable but it is semantically invalid. For example, the feature "hole" may be placed so that it intersects the boundary of the member and in effect the hole changes its shape and may not be able to serve the designated function.

As to the third question, conversion from one set of features to another amounts to rearranging a component model expressed in terms of one set of features in a model of the component expressed in terms of a different set of features. This process requires selection of information from the primary representation (and ignoring some part of the information), then other information, derived from the secondary viewpoint is added and the new amount of information is structurized by aggregation into secondary features |10|.

The process of conversion from design features to manufacturing features is non unique and is difficult to formalization. The major difficulty lies, however, in the conflict between the postulate for designer's freedom to create new feature types and developing computer programs for the process planning.

5. Conclusion

The present state of product data modelling does not satisfy neither the current needs od CIM systems, nor does it meet designers expactations.

Designing of mechanical systems needs more than geometric information to allow for requirements of the whole life cycle of a product, and particularly for manufacturing. A concept of features that associates a specyfic engineering (semantic) meaning with the property attributes seems to provide considerable progress in comparison with current computer geometric modelling systems. However, to use the full power of the feature-oriented systems several difficult problems have to be solved. Among of these are origination, interaction, ans conversion of the features. Further progress requires elaboration of more intelligent and flexible computer systems which are capable of assimilating various aspects of engineering experience and converting it in relevant constraints.

REFERENCES

[1] Rohatyński, R.: Modelling in Engineering System Design, Proceedings of ISS Conference: Problems of Constancy and Change, vol.2, Budapest 1987.

[2] Hubka, V.: Theorie Technischer Systeme, Springer Ver., Berlin 1984.

[3] Finger, S., Dixon, J.R.: A Review of Research in Mechanical Engineering Design, Part II: Representations, Analysis, and Design for the Life Cycle. Research in Engineering Design, vol. 1, Nr 2, 1989.

[4] Pratt, M.J.: Solid Modelling and the Interface between Design and Manufacture. IEEE Computer Graphics and Applications, July 1984.

[5] Pratt, M.J., Wilson, P.H.: Requirements for Support of Form Features in a Solid Modelling System. Raport R-85-ASPP-01, CAM-1, June 1985.

[6] Dixon, J.R.: Designing with Features: Building Manufacturing Knowledge Into More Intelligent CAD Systems. Proceedings, ASME Manufacturing International 88, Atlanta, GA, April 1988.

[7] Shah, J.J.: Conceptual Development of Form Features and Feature Modelers, Research in Engineering Design, vol.2, Nr 2, 1991.

[8] Zamanian, M.K., Fenves, S.J., Thewalt, C.R., Finger, S.: A Feature-Based Approach to Structural Design. Engineering with Computers, vol.7, Nr 1, 1991.

[9] Wierda, L.S.: Linking Design, Process Planning and Cost. Information by Feature-based Modelling. Journal of Engineering Design, vol.2, Nr 1, 1991.

[10] Rosen, D.W., Dixon, J.R., Xin Dong: A Methodology for Conversions of Feature-Based Representations. Proc. ASME DTM Conference, Miami, Sept. 1991.

PROBLEME BEIM MODELLIEREN DER PRODUKTE IN SYSTEMEN CAD UND CAM

Zusammenfassung

In dem Referat werden der gegenwärtige Zustand und Laufende Richtungen des computergestützten Modellierens "product data" besprochen. Zuerst werden der Begriff des Modells und Klassifizierung der Attribute dargestellt und später kommt die Auseinandersetzung mit dem rein geometrischen Modellieren des Produktes, weil diese Art und Weise die Bedürfnisse des Designers nicht ganz zufrieden stellt. Es werden verschiedene Betrachtungsweisen des Modells eines Produktes behandelt. Demnächst wird der Begriff "a feature" als grundlegendes Element des rationellen Denkens "in engineering" eingeführt. Der Einsatz von "features" und hauptsächliche Schwierigkeiten bei Überführung in CIM-Systeme werden hingegen abschliessend behandelt.

ZAGADNIENIA MODELOWANIA WYTWORÓW W SYSTEMACH CAD I CAM

Streszczenie

W referacie omawia się obecny stan i bieżące kierunki komputerowego modelowania danych o wytworach. Najpierw podaje się pojęcie modelu i klasyfikację atrybutów, a następnie formułuje się krytykę czysto geometrycznego modelowania wytworu, ponieważ ten sposób reprezentacji nie jest adekwatny do potrzeb projektanta.

Omawiane są różne spojrzenia na model wytworu. Wprowadza się pojęcie "a feature" jako podstawowego elementu języka rozumowania inżyniera.

W końcu pracy omawia się zastosowania "features" i trudności wprowadzenia ich do systemów CIM.

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