Description of Structure of Dependencies in Product Model

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Abstract-This paper introduces a methodology for the organization of dependencies in classical product models. The reported work is intended as a contribution to the solution of the problem of tracking associative connections along chains of modeled product objects at analysis of consequences of changes of modeled objects during development of products. The author proposes an information content oriented extension to classical data oriented product models. Tracking of consequences of changes of modeled objects on other modeled objects is assisted by concepts of change affect zone and change chain. The approach to model construction process is based on modification of a previous state of the model for development of the product. This paper starts with an outline of engineering in virtual space as well as relevant researches from the author and the literature. Following this, the proposed extended modeling is explained concentrating on change affect zone and change chain. Next, information content oriented product model and its connection with classical data oriented product model are detailed. Finally, possibility of implementation of the proposed modeling in professional product lifecycle management (PLM) systems is discussed.

Key-Words: - Product lifecycle management, Product modeling, Information content oriented modeling, Management of changes, Change affect zone, Change chain

1 Introduction

Scene of competitive product development has moved into global computer systems during the past decade. These systems can be extended to the entire lifecycle of products. Shortened innovation cycle and increased demand for durable and highly engineered products stimulated development of simulation and decision assistance in product modeling and analysis systems. Demand for intensive communication between humans and modeling procedures requires much more information about dependencies for calculation of parameters of modeled objects and evaluation of consequences of proposed or accepted new values of those parameters. The problem is that conventional product modeling systems are characterized by increasing number of unstructured dependencies. When a parameter of one of the modeled product objects changes, it is practically impossible to reveal all possible allowed and not allowed consequences of this change.

As a contribution to solution for the above problem, author developed structural description of dependencies amongst engineering objects in product model. He considered method for restriction of the search space of dependencies into an actual subspace. Actual dependencies are selected for the propagation of changes.

For the purpose of the reported research, the author introduced the concept of engineering object parameter dependent affect zone.

Beyond modeling by dependencies, contribution by the author includes two additional methods. They are description of information content of dependencies and introduction of concept of engineering object for description of any physical or logical modeled objects in lifecycle of product. Engineering object is characterized by information content of its attributes and dependencies.

This paper starts with an outline of engineering in virtual space as well as relevant researches from the author and the literature. Following this, the proposed extended modeling is explained concentrating on change affect zone and change chain. Next, information content oriented product model and its connection with classical data oriented product model are detailed. Finally, possibility of implementation of the proposed modeling in professional product lifecycle management (PLM) systems is discussed.

2 Product Engineering in Virtual

During model based development of a product, construction in a three dimensional model space utilizes high number of modeling procedures for the definition of elements, structures including high number of various dependencies. Equations, logical relations, rules, checks, and responses are available for the definition of associative relationships. The chance for high-level engineering activities is currently decreased by poor representation and processing of associative connections. Reason is definition of high number ad-hoc and poorly structured associative connections in the form of pure data descriptions of relationships.

The author of this paper analyzed the above situation and concentrated his work on improving product modeling by a new method for organized description of associative definitions amongst modeled objects. Efficient support for decision making on parameters of engineering objects would require automated survey of actual associative connections. This is impossible in current product modeling because it cannot provide transparent structure of associative connections. Manual tracking of connection chains is time consuming and is a main source of errors and mistakes. As a consequence, responsible engineers often instruct other engineers to define associative objects only within units of products.

In order to placing the reported research in the related research activities, several relevant results are cited below from researches in human activities and product model creation (Fig 1). Issues are information modeling, extraction of views from product information, form feature recognition, knowledge capitalization, definition of associative features, and multi-disciplinary character of work of engineers.

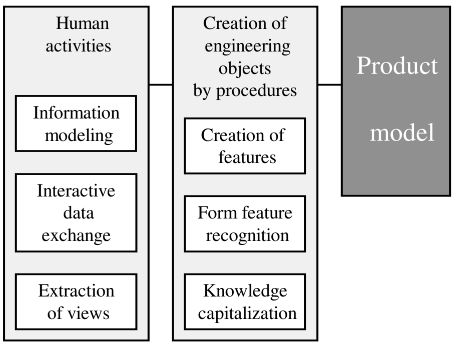

Fig. 1. Essential issues in present industrial modeling

In the area of information modeling, IDEF1-based process-oriented information modeling methodology is proposed in [1]. The IDEF0 process model is integrated with the enhanced IDEF1 information model. The result is easy identification and analysis of information requirements through the corresponding process models. Recent method is extraction of application specific product data subsets from large and very complex product models in the form of views. Views support efficient product modeling. An integrated design framework is shown in [2] where the product model used by the process planner is extracted from the global product model by filtering.

Well-engineered and styled shapes of mechanical parts are constructed in the course of a sequence of shape modifications by form features. When a shape is constructed by a different system or shape modification information is unavailable, sequence of shape modification can be reconstructed by feature recognition. In [3], graph based and "hint" based methods, convex hull decomposition, and volume decomposition-recomposition techniques are introduced.

Including knowledge in product models is a critical issue but not a success story. Approach and methodology in this paper serves establishing a new branch of research in knowledge-based methods. Numerous recent works show the actuality of research in knowledge based product models. In [4], an approach to definition and mapping of knowledge, based on the point of view of an expert in manufacturing is discussed. The authors of [4] propose tools and models for knowledge capitalization.

Research in associative connections generally focuses onto partial problems of product models and cannot provide general solution. Paper [5] presents associative assembly design feature as a new type of features. This new feature allows associations between parts that have not been defined geometrically, between geometric entities defining interfaces between parts, and between part geometry and intermediate geometry used to define a part. Extension to traditional assembly feature properties allows product architectures to be defined using features. Despite process orientation in product data management (PDM) systems, support of flow of product information is weak in current engineering systems. In paper [6], interfacing knowledge oriented tools and CAD application is identified as a technical gap for intelligent product development. The authors of [6] consider definition of associative features in the form of self-contained and well-defined design objects as essential for high-level reasoning and the execution of decisions.

Characteristics of products require multidisciplinary work at their modeling. Multidisciplinary activities are done with participation by high number of areas of expertise. Paper [7] emphasizes very multi-disciplinary character of work in early stage of aircraft design. Large variety of specialized tools must be compatible. Otherwise, interface problems are the consequence.

The author of this paper participated in several projects in product modeling. The most relevant ones are in the following. Improvements were proposed for industrial modeling in CAD/CAM systems towards more intelligent and human centered engineering processes (Fig. 2). Integration of product data management (PDM) with product modeling was supposed. In order to establish an enhanced human-computer interaction (HCI), human intent were analyzed then modeled [8]. Intent of any person who has influence on decisions of engineers is considered. The knowledge is always corporate accepted one and it is defined, filtered, and accepted according to human intent [9]. Method for associative engineering object definition and product behavior analysis driven management of product changes were published in [10]. As complex model object for closely connected product and other related objects, the authors introduced the concept of integrated model object (IMO) in [11]. As a preliminary analysis for the integration of the above methods with the methodology of modeling in CAD/CAM systems, the author of this paper surveyed relevant problem solving techniques available at model-based engineering [12].

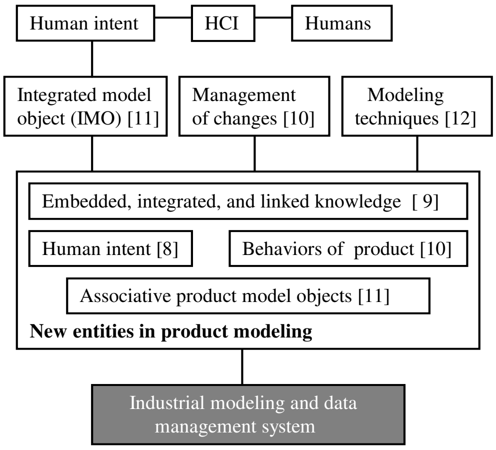

Fig. 2. Results of pervious research

3 Extended Product Modeling

When a brief definition of recent product modeling is necessary, it can be summarized as definition of engineering objects, relating them with other engineering objects, and calculation of their parameters. Relating is defined amongst parameters of the related engineering objects. However, there is not available description for structure of relationships. In order to fill this gap, the author proposed three methods for organized description extension to the above-modeled dependencies of engineering objects (Fig. 3). They are description of dependency structure, definition of affect zone for engineering object parameters, and modeling of information content of associative connections.

Dependency structure is represented as a graph where nodes are engineering objects represented by the actual parameter or parameter set, and arcs are associative definitions. Change affect zone (CAZ) of an engineering object parameter defines a restricted search space in the graph for consequences of its change. Information content may include any things about origin and intent of an associative definition that is needed by any engineering activity during the lifecycle of a product. Information content depends on task, humans, and environment.

In Fig. 3/a, unstructured relationships are placed in a graph as they are defined at product development. The proposed methods facilitate recognizing and mapping of change affect zone (CAZ) of a modeled object and change chains (CHC) in the graph. Consequences of changes are propagated along CHCs.

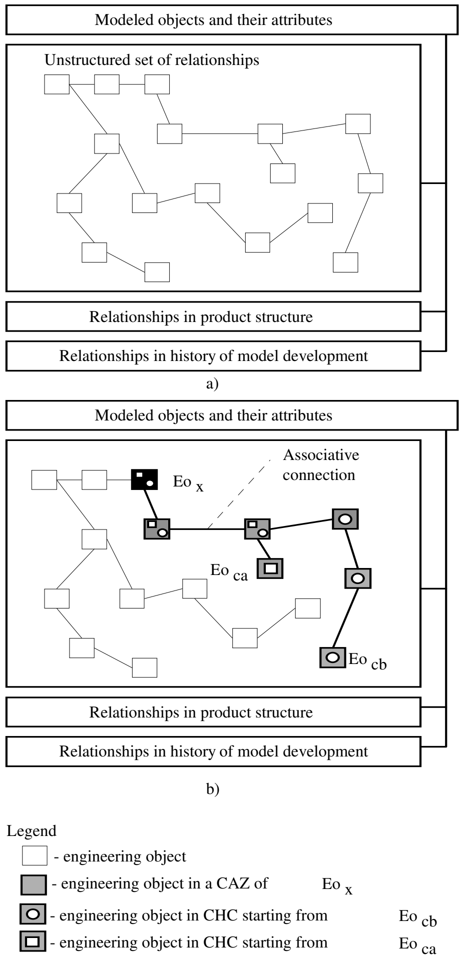

Fig. 3. Extended approach to product modeling

Fig. 4 outlines role and place of associative connections in a product model. Essential groups of elements for construction of a product model and their basic associative connections are shown. Elementary product entities are applied as construction elements of parts and are connected as elementary shapes, etc. by their parameters. Components of products are associative with elementary entities, other components, entities for their analysis, and manufacturing processes. This approach is suitable for both current product modeling and the modeling extension by the author. Models are defined and modified by knowledge driven and human controlled modeling procedures.

The proposed information content extension to classical data oriented product model is outlined in Fig. 5. Current classical engineering modeling systems are composed by elements and associative connections in product models and modeling procedures. Extension includes procedures for the definition and processing of human intents, information contents, and associative procedures.

Extension to product model includes the following new entities.

- Product object behavior and situation for its definition [11].
- Multiple human intent filtered knowledge for embedding, integration, or linkage [8], [9].
- Change affect zone (CAZ).
- Change chain (CHC).
- Structure of associative connections in a purposeful form of graph.
- Adaptive action to carry modification information [10].

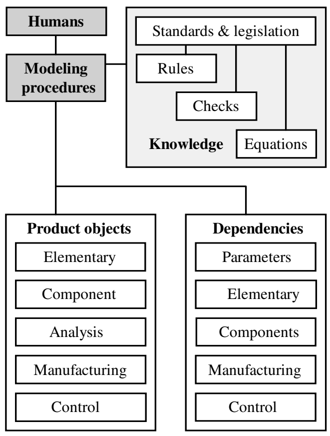

Fig. 4. Essential dependencies in product model

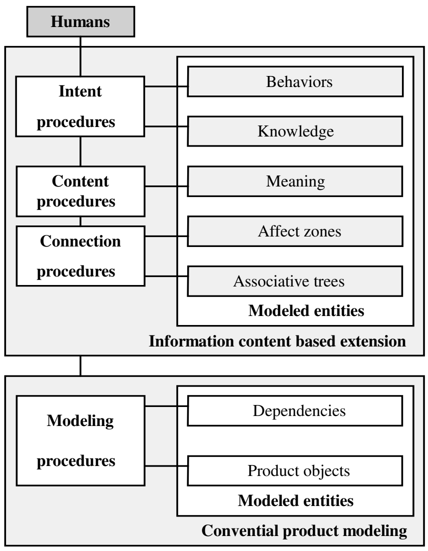

Fig. 5. Extension to product classical modeling

Structure of associative connections requires very flexible and traceable description with a representation of different states of adaptive actions for the execution of changes along chains of associative engineering objects in affect zones.

Any parameter of any engineering object may be modified by different associative connections. At the same time, it can receive different change attempts. A node in the structure of associative connections is an intersection of different change chains (CHC) for different parameters. At the same time, a parameter may have different connections (Fig. 6). A connection may receive different change attempts in different change chains. Status of a change attempt in a change chain may be "under revision", "under discussion", "argued", "decided". Values of parameters for product variants and solution alternatives may be also mapped to the node.

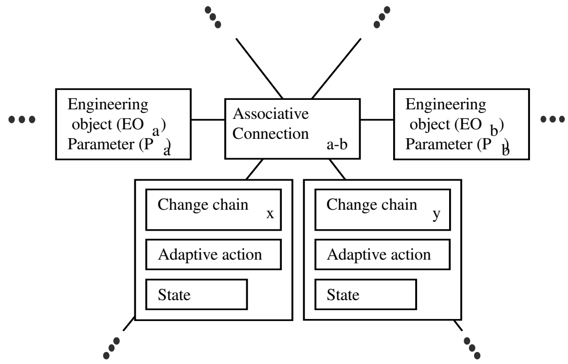

Fig. 6. Associative connection in two change chains

4 Change for Information Content

Current product modeling systems represent high level and advanced form of data oriented modeling. Most of attempts to increase information content in a product model were failed because knowledge was stored as data and its content was really carried by human. In order to efficient decision assistance, the author completed the conventional data oriented model by information content oriented model sector. Information content is arranged in a multi-level schema. Mapping of information content representations also requires multilevel structure of data representations.

For better understand of data and content orientation of model and modeling, a comparison is given in Figs. 7. and 8. The author recognized that data oriented product model contains description of engineering objects by their attributes, relationships of attributes, and history of model construction (Fig. 7). Elements and units in model descriptions are defined for engineering objects. Definition of engineering objects and construction of product model are supported by engineering object and structural information specific modeling procedures. The proposed new multilevel structure of data oriented product model is also shown in Fig. 7. Identification of engineering object points to application mainly for the purpose of specification of essential design information. Detailed description of an engineering object is preceded by definition of its associative connections (AC) with other engineering objects. AC carries information about its function e.g. engineering calculation, placing, DOF. Engineering object is described by its attributes. Representations are mapped to attributes.

As it is stated above, information content of product objects and other related engineering objects is not described in the data oriented model. As a contribution to a possible solution for this problem, the following main characteristics of the proposed content oriented product model were decided as objectives.

- Content information must assist effective communication between engineers and data oriented modeling procedures.
- Content information enough for explanation and evaluation of modeled objects and their environment must be represented in product model for modeling tasks.
- Content information must be enough for saving compliance of product model data with intent of responsible engineers.
- Knowledge from all relevant sources must be defined and involved as information content.
- Information content acts as an extension to data oriented description and it is associative with data descriptions.

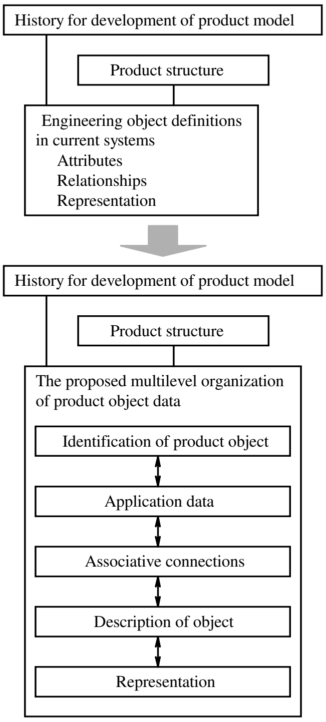

Fig. 7. Multilevel structured data oriented product model

Multilevel structure of the information content oriented product model is shown in Fig. 8. Because an extension of current data oriented product model is aimed, multilevel organization of data oriented model (Fig. 7) is applied as an interface between the conventional data oriented and the information content oriented sector of product model. Engineering activities are initiated by definition of human intent and are aimed at making decisions on product model objects (Fig. 8). Making, revising, and reproduction of interrelated decisions on engineering objects need information about meanings of concepts and contexts of the decided items, and engineering objectives.

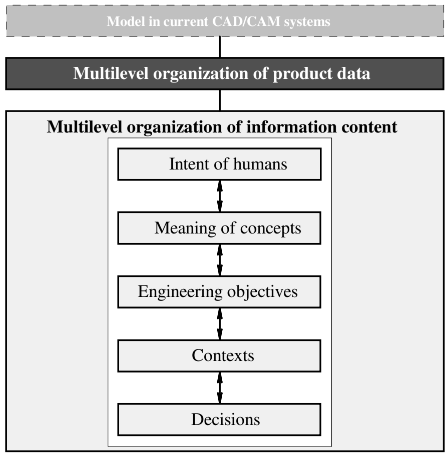

Fig. 8. Multilevel organization of information content

5 Implementation and Future Plans

The original objective of the reported research was development of methods that have a great chance for implementation as an extension to industrial PLM systems. PLM systems include extensive modeling software tool sets for CAD/CAM and CAE purposes (Fig. 9). Related functional units of PLM systems are for management of product data in case of different modeling systems, interoperability to enable data exchange with non-integrated modeling systems, as well as group work and Internet portal communication. Modeling procedures, model data structures, and the graphic user interface can be accessed from programs in the information content extension developed by using of tools that are available in PLM systems. Access is available through standard application programming interface (API).

Laboratory of Intelligent Engineering Systems (LIES) of the Institute of Intelligent Engineering Systems, John von Neumann Faculty of Informatics, Budapest Tech. has been equipped with leading industrial PLM, intelligent computing, and mathematics software, among others for the purpose of experiments with information content oriented modeling. Research work in information content modeling will concentrate on better understanding of content model entities and their interconnections with data oriented model entities in the next future. Main issues are coexistence and relationships of content and data oriented model entities.

6 Conclusion

Fantastic development of product modeling solved data type problems. The next step of development of product modeling in the well-established data oriented virtual space is increasing information content, and tracking consequences of modification of product objects and definition new product objects in the virtual space. This paper is a contribution to this work. Its main contributions include, graph for organizing high number of unorganized associative connection in product model, change affect zones and change chains to enhance understanding of propagation of consequences of modification and creation of modeled product objects. On of the essential task is handling of multiple affects on parameters describing modeled objects. Essential objective of the reported research work is development of information content oriented modeling methods as extension to well-established data oriented modeling methods in recent conventional PLM system.

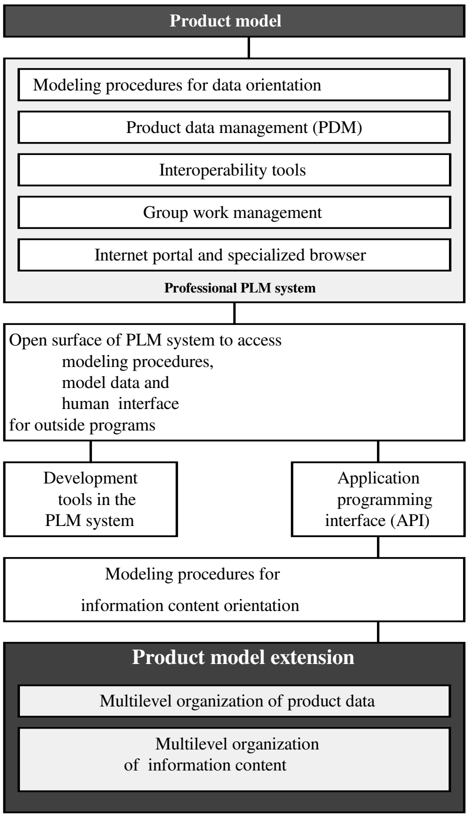

Fig. 9. Implementation in PLM systems

7 Acknowledgment

The author gratefully acknowledges the grant provided by the NKTH and OTKA Fund for Research of the Hungarian Government. Project numbers are K 063405 and K 68029.

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