Intelligence for the Assistance of Engineering Decisions in Associative Product Modeling

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Abstract: Highly integrated and extended application of product model based engineering using product lifecycle management systems is the most important recent achievement in computer aided engineering. Continuous development of products and their variants placed management of changes of engineering objects during development of product in the centre of investigations in product modeling. The authors joined to these efforts by a new methodology using extended definition of features. In this paper, definitions of active features for object descriptions are introduced and a four-leveled model for definition of behavior, adaptivity, and associativity features is proposed for highly integrated product models. Following this, engineering object descriptions in highly integrated model units and handling of effects related to changes of engineering objects are proposed. Next, difference between the recently prevailing and the proposed modeling is detailed. Finally, including knowledge in a three-leveled model, definition of human intent filtered knowledge, and conflicts at decisions are detailed as issues at modeling of engineering objects.

Keywords: Product modeling, support of decision making, behavior based modeling, human intent modeling

1 Introduction

Great change in engineering has been generated by arrival of engineering modeling systems for lifecycle management of products. One of the critical problems is handling of changes. Emphasis on definition and relation of parameter sets describing engineering objects in recent product modeling systems supports definition of change chains resulted by change of an object. The situation is much more complicated because a decision on an engineering object depends on several other decisions by engineers who may not available at later changes of engineering objects during their development, variant creation, and custom demanded modification. The authors propose a method to solve the problem of handling modification using a model consisting of descriptions of interrelated engineering objects. Engineering objects are for parts and substructures of products, results of analyses, manufacturing processes, and all other objects definition of which is necessary for engineering activities during lifecycle of a product from the first idea to recycling. Humans who are responsible for engineering activities regarding associative modeled objects that must be changed as a consequence of the attempted change must accept an attempt for modification.

There are several recent works of the authors in close connection with the reported research. They analyzed modeling in CAD/CAM systems [1], application of behavior definitions and adaptive functions to assist decisions and propagate their effect [2], modeling of human intent as background of decisions [3], and integration of human intent modeling in modeling of mechanical units [4]. They proposed a modeling for handling of changes in models of engineering objects by propagation of effect of changed entities [5].

As a preliminary of the reported work, some basic concepts were considered from the area of distributed virtual systems of similar purpose as summarized in [6]. Intelligent agents were conceptualized and developed by several researchers in recent years for interactive simulation in environments similar to as analyzed by the authors. Some of the related concepts, considered by the authors were published in [7]. The authors considered advanced methods of information modeling, model description and application specific reference modeling for their generic model and the related modeling. This allows an implementation of the proposed modeling in product model environments based on the Standard for Exchange of Product Model Data [8]. Description of form features [9] and surfaces in boundary representation represents an outstanding development of shape modeling in the last decade.

Modeling systems are highly based on advanced software development and intelligent computing methods. Author of [10] examined how UML, as the most widespread modeling tool of object-oriented software development, supports practical user interface development. He proposed application of the usage interaction model and the usage control model, each of which can be described by supplementing well-known UML diagrams. Paper [11] deals with fuzzy based implementation of backward identification method with an emphasis on advantages and disadvantages of this method. It also suggests application of the proposed method.

In this paper, definitions of active features for object descriptions are introduced and a four-leveled model for definition of behavior, adaptivity, and associativity features is proposed for highly integrated product models. Following this, engineering object descriptions in highly integrated model units and handling of effects related to changes of engineering objects are proposed. Next, difference between the recently prevailing and the proposed modeling is detailed. Finally, including knowledge in a three-leveled model, definition of human intent filtered knowledge, and conflicts at decisions are detailed as issues at modeling of engineering objects.

2 Definition of Active Features for Object Descriptions

Engineers work with engineering objects. Model of a product is a structure for descriptions of engineering objects. This approach to modeling of products by the authors is shown in Fig. 1. Features describe engineering objects. Component objects are described as elementary and knowledge features. Structure and relationship features describe structural and relationship objects, respectively. An elementary feature can be placed in one or more structures. The authors have completed the above conventional choice of features. Associative connections of objects are described as associativity features. Engineering objects or their structures are characterized by one or more behaviors. Adaptivity features control modifications of engineering objects. Behavior and adaptivity features are introduced for the description of these active objects. Elementary, structural and relationship features are capable to describe variants of engineering objects.

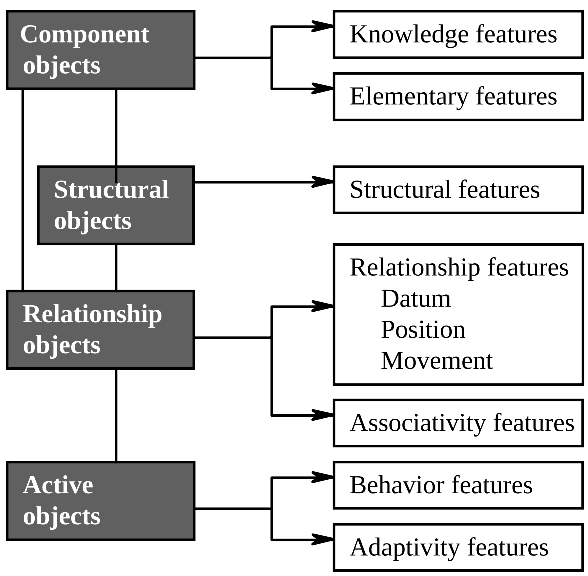

Figure 1
Engineering objects and their descriptions in product model

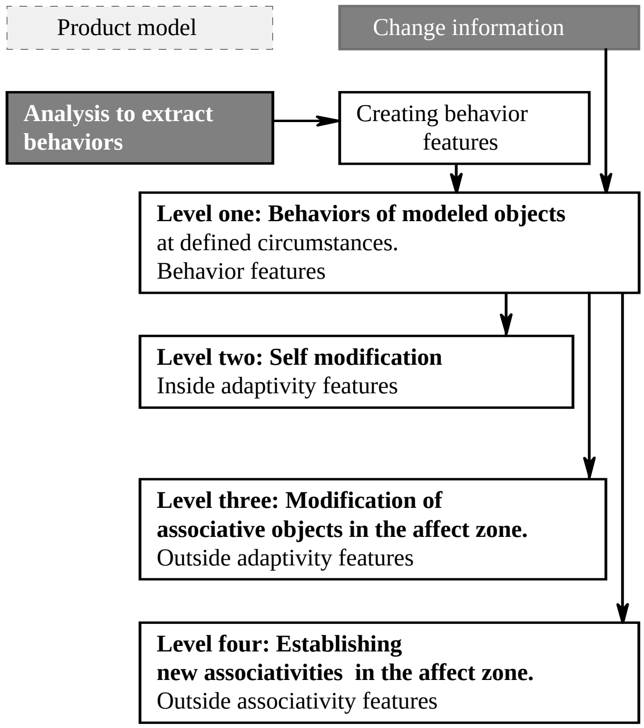

Figure 2
Four leveled model to handle behaviors and adaptivities

A four-leveled model of behavior and associative object definition related activities is applied in a highly integrated product model (Fig. 2). Elementary, structural and associativity features, in generic or instance product models, are applied at creation and modification of generic and product related behavior features. Adaptive actions are defined for inside and outside of an arbitrary unit of a highly integrated product model. On level one, actual behaviors of the modeled engineering objects are defined for given circumstances. On level two, inside adaptivity features are created and applied for modification of model object entities as a consequence of communicated changes. On level three, outside adaptivity features are created and applied for making attempts to modify model entities outside of the model object. Behavior features may reveal a need for modifications of non-associative engineering objects, inside or outside. In this case, new associativities are to be defined on the level four. Following this, repeated attempt to modify the newly associative objects, as an activity on level three is necessary.

3 Engineering Object Descriptions in Highly Integrated Models

Descriptions of engineering objects such as part and shape elements composing it, relationships of parts, results of analyses, manufacturing processes, are proposed to integrate in complex model objects. Called as integrated model objects, these communicate with the modeled and not modeled word outside of it: receive input effects and create output effects. Effects are related to changes of engineering objects and generated and processed by behavior-based analysis (Fig. 3) in the proposed modeling. Behaviors of the modeled objects are elaborated by using of circumstances. Circumstances are defined by using of elementary functions, responses, and actions. Circumstances and situations organize behavior-based knowledge. As a consequence of the behavior-based analysis, key functional element of an adaptive model object is situation handling. It coordinates effects, structures, and behaviors, identifies circumstances, sets situations, and produces reactive behaviors.

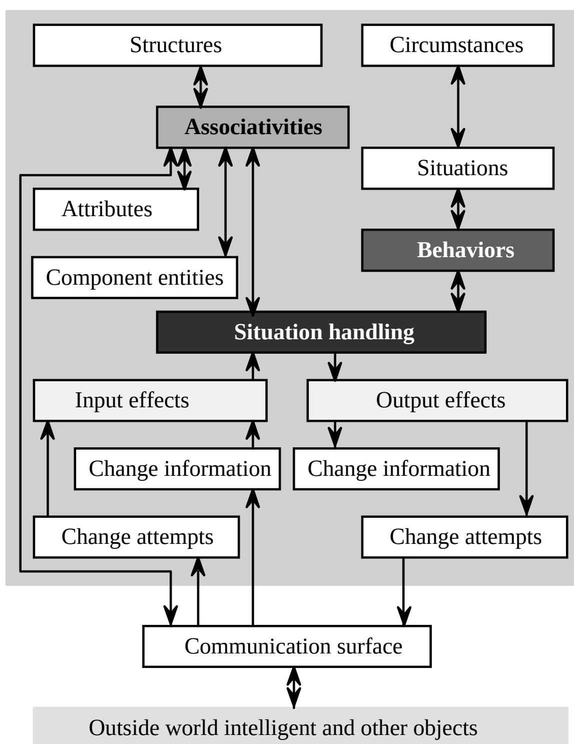

Figure 3
Handling of changes by situation based behavior analysis

Component entities and their attributes are accessed through structure descriptions, by the help of associativity definitions. Objects in the world outside of an actual integrated model object produce input effects and receive output effects through a communication surface. Structure and component entities and their attributes are changed according to decision by situation handling.

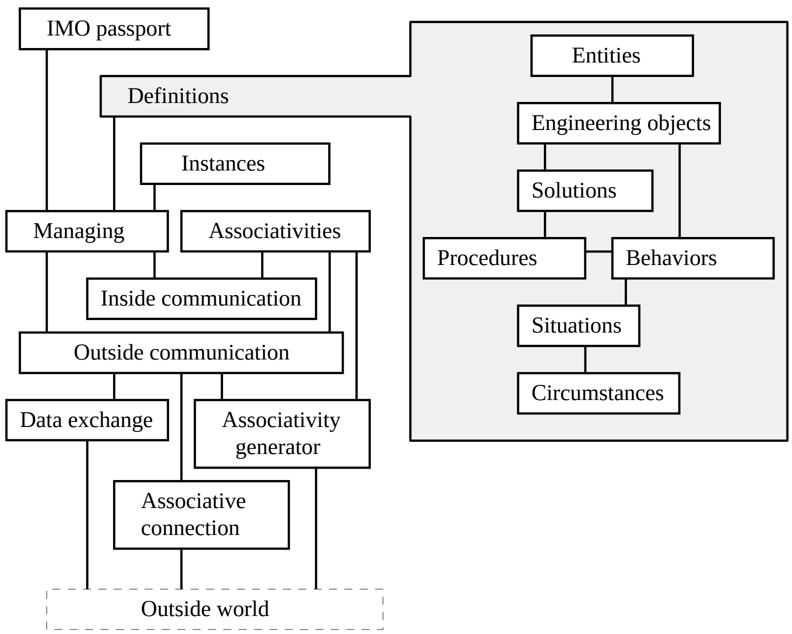

Figure 4
Structure of an integrated model object)

Integrated model object comprises associative entities. It constitutes a unit organized and configured for processing, inside, and outside communication. Integrated model object works in connection with conventional modeling where modeling, group work, and product data management tools are available for handling model entities, collaboration of engineers as well as process and multimodeling based management of product data. In the structure of an integrated model object (Fig. 4), the passport gives general status, acceptance, permissions and other access and application related information. Other important structural elements of an integrated model object are definitions, instances, and communications. Procedures are organized by managing function. Inside and outside communications are handled along associativities. Sets of new associativities are generated according to newly emerged demands for communication. As an auxiliary function, communication also can be done by conventional data exchange with systems without associative connection. Fig. 4

also outlines main categories of definitions. Engineering objects are described by entities. A solution comprises a set of entities representing interrelated engineering objects for a well-defined engineering purpose. Behaviors are defined according to the goals associated with the modeled engineering objects. Behaviors are analyzed for situations. A situation is composed by a set of circumstances.

4 Adaptive Actions on Engineering Objects in Product Modeling

In this section, difference between the recently prevailing and the proposed modeling is detailed. During the last decade, a mixed application of feature based, parametric, associative and adaptive methods of modeling (Fig. 5) resulted in great advancements in description of engineering objects. Models are composed by elementary features, their instances, structure features, and associativities. For example, a part is an elementary feature. Its instances are placed in an assembly. Structure feature is the assembly tree and associativities are applied at placing the part in the assembly.

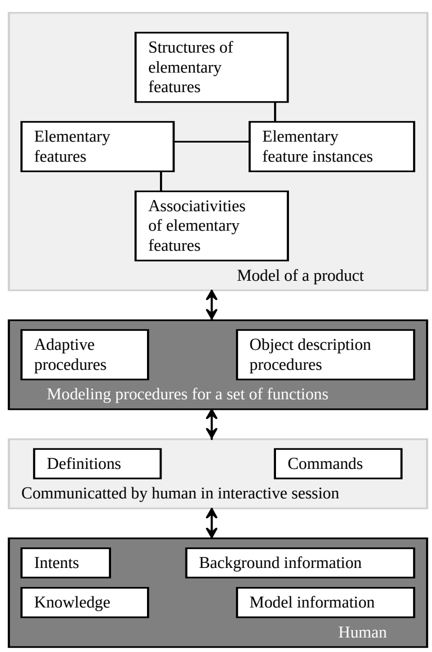

Figure 5
Modeling in recent CAD/CAM systems

As other example, a part feature is a structure of shape modifications. In this case, elementary feature is a form feature, its instances can be placed in arrays, and associativities are applied between elements of a contour.

Adaptive modeling has the capability of modification of entities and their parameters by using of initial rough results. For example, a finite element mesh is generated as a rough one. Then adaptive meshing refines it. Object description and adaptive procedures are placed in modeling systems outside of the model. Exchanged model information is handled by modeling procedures other than the original ones by which they were created. It is impossible to make modeling system that has the capability of understanding all exchanged models correctly.

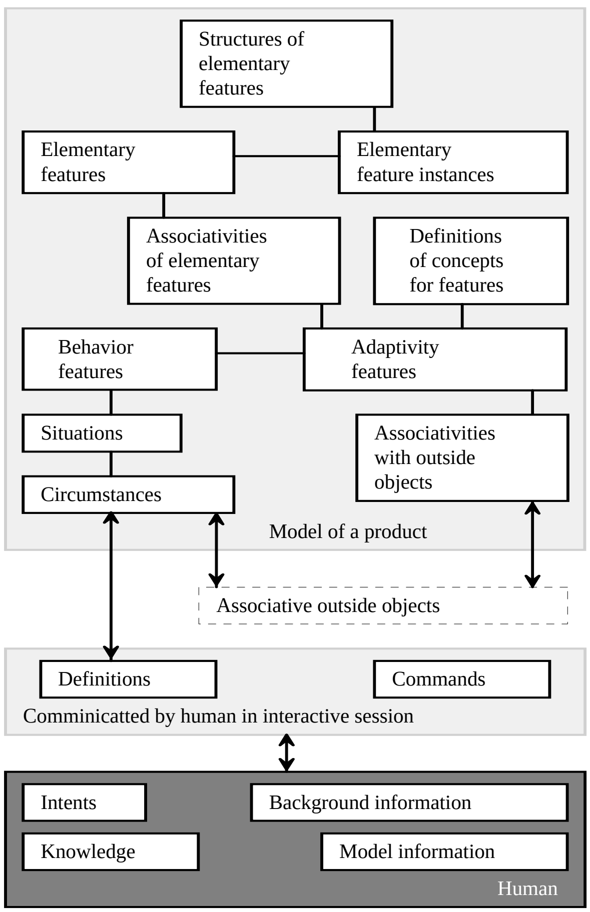

Figure 6
The proposed product modeling

Human gives definitions and commands in an interactive way to control the modeling process.Correctness, appropriateness, and consistency of the model are established and controlled directly by the quality of human activities. In this engineering process, human cannot concentrate on essential decisions because the so many details to be handled.

The proposed product modeling is relied on description of behaviors and adaptivities (Fig. 6). An integrated model object consists of three modules. They are inside modeled object information, behaviors and adaptivities. The engineering strategy for characteristics of the product is distributed amongst behaviors. A behavior represents an independent design objective. Behaviors may need coordination. Any information from the engineers and outside of the domain of modeling is considered as circumstance. Circumstances are applied at creation of situations. Situations are processed by behaviors. At the same time, behaviors generate information for adaptivities for the modification of the model or associative outside objects. Adaptivities also supply model object information for the behaviors. The method of modeling is wide application of the feature principle.

5 Knowledge in Product Model as Representation of Human Intent

In every day industrial practice, decisions of engineers are done according to intent of engineers. The authors considered role of human intent and conceptualized an integrated and environment adaptive modeling of products where knowledge is included in model as representation of human intent. They handle attempts for creation and modification of models as communication process of human intent. Human intents are added to a model object from the creation of the first entity to end of its life. Intent sources are engineers who work on the actual project, all other engineers involved in concepts, methods, knowledge and information applied at modeling, experts included in the project, and other outside effects as standards and legislation.

A simplified schema of including knowledge in model of engineering objects is shown in Fig. 7. Some firmly tied knowledge is embedded in models. Other knowledge is integrated or imported. Imported may need translation before application. Model is defined on three levels that ensures implementation of the proposed modeling as an upgrade of an existing modeling. On the application level, model includes entities for description of some modeled objects by features and their attributes. On the level of relationships, associativities are defined amongst model entities and their attributes. This can be a simple rule to calculate some attribute values or even a complete taxonomy. On the level representations, best appropriate description is established for entities and their relationships. Modeling of design intent can be applied for development a system that describes and processes all information about a category, type or series of a product. Intent bank provides information about previous and related decisions and it can be used at decisions similar to some previous ones. Lists can be extracted, for example, for actual problems to be solved, unsolved problems during earlier product design and similar decision processes from successful engineers.

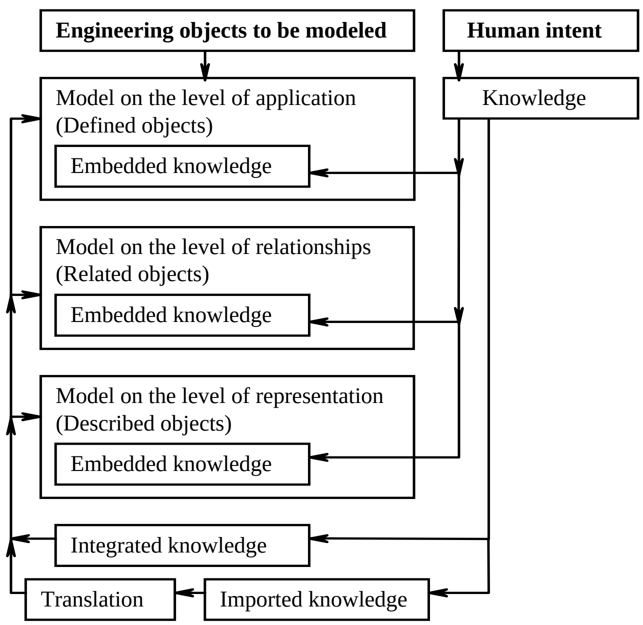

Figure 7
Including knowledge in a three leveled model

Active engineer who is responsible for modeling (Fig. 8) defines most of intents. In case of group work of engineers, two or more engineers may share a decision so that intent cannot be assigned to a single human. In this case, different engineers define different elements of intent. Active engineer uses knowledge, defines intent or retrieves own experience in the form of knowledge, uses intent of other engineers and considers intent of other engineers in the form of retrieved knowledge. In some cases, engineer is not allowed to omit intent of chief engineers and other persons who decide on application of standards, laws, etc. Intent definitions also can be used at creation of knowledge description for appropriate knowledge sources. In Fig. 8, model creation and modification are done by actions of active engineers or by adaptive actions of procedures. Human intent based application of knowledge is inherently restricted.

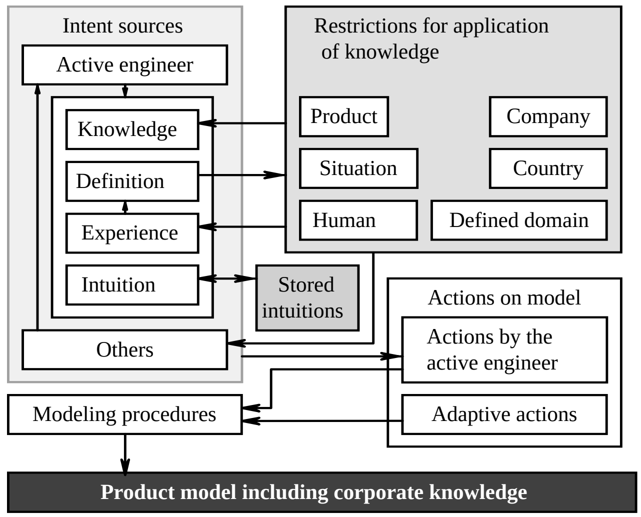

Figure 8
Intent filtered knowledge

Other restrictions are defined during intent related knowledge definition regarding product, situation, human, company, domain, and country. This methodological element of intent modeling points to one of the most important characteristic of knowledge: It is not generally applicable and it is accepted with criticism. Security measures to avoid unauthorized access to knowledge are included.

Knowledge features are application-oriented descriptions of strategies, solutions, experiences, etc. At the same time, model includes decisions and design intent [5]. One of the issues for coordination of behaviors is resolution of conflicts (Fig. 9). Conflict may be originated from capability related problem or breaking some human intent. Conflicts need coordination of behaviors. Capacity as the maximum available resource may restrict resources such as engineers, model entity types, parameter ranges and values, solutions, methods, and facilities. Restriction controls application of resources. Results of analyses and experiences also may suggest restricted or preferred solutions. Engineers, who are responsible for their decisions have responsibility-based privileges. Results of decisions are represented by appropriate product model information. Other intent related information comes directly from the user dialogue. Conflicted intents occur in every day engineering practice. Other sources of conflict of intents are outside world objects, which may not accept attempts for their modification by adaptivity module of an integrated model object. Intent breaking may come from stored or communicated intents that contradict actual intents enforcing new or modified decisions. Purpose of threshold knowledge is saving essential intents and quality of decisions. Strategies, decisions, and solutions are stored for later decisions.

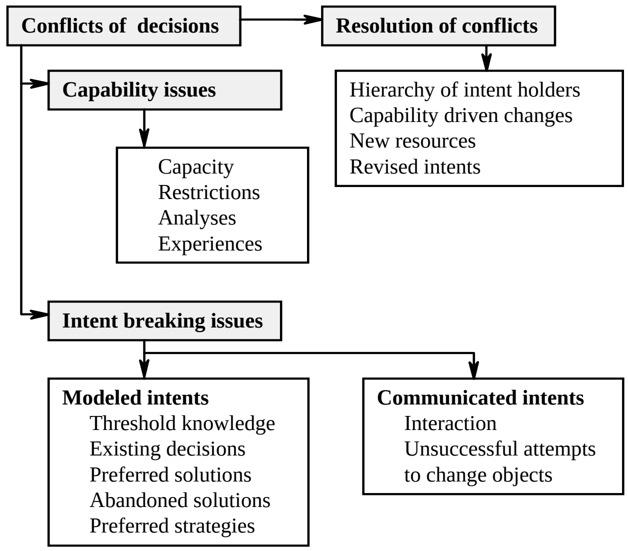

Figure 9

Conflicts at decisions about engineering objects

Conclusions

The authors propose a method to solve the problem of handling modification in a model consisting of descriptions of interrelated engineering objects. Essential elements of the proposed solution include description of engineering objects by features, integration of descriptions of modeled objects, and a four-leveled model to handle behaviors of modeled objects and adaptive actions for changes of engineering objects. Methods are proposed for handling of changes of engineering objects by situation based behavior analysis, design intent originated knowledge content of models, and definition and resolution of conflicts at decisions on engineering objects. Integrated model object is introduced for description of associative models of closely related engineering objects. It constitutes a unit organized and configured for processing, inside, and outside communication.

Intent sources are engineers who work on the actual project, all other engineers involved in concepts, methods, knowledge and information applied at modeling, experts included in the project, and other outside effects as standards and legislation. Engineering objects are for parts and substructures of products, results of analyses, manufacturing processes and all other objects definition of which is necessary for engineering activities during lifecycle of a product from the first idea to recycling. Possibility for implementation of the method is based on support of definition of change chains resulted by change parameter sets describing engineering objects in recent product modeling systems.

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