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Processes in Virtual Engineering Spaces

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***Abstract*— Recently, product models serve lifecycle product information for wide area of engineering activities. This extended purpose results very large and complex product models with high number of relations. Restricted capability of product models for representation of some important elements of the human thinking process during definition of engineering objects in current industrial modeling systems makes it impossible to evaluate, revise, and change hundreds of already decided engineering object parameters. In this paper, a new methodology and several related processes are introduced in order to better communication between human and model generation processes. The main essence of the proposed product modeling is that human intent controlled development of engineering objects is realized by an extension to current industrial product model called as model of information content. Engineering objectives and contextual connections are defined as human intent driven features and applied at decision on engineering object parameters and at control of processes for engineering object parameter optimization and relating. The proposed modeling is connected to knowledge handling and knowledge based advisory functionalities of industrial product modeling systems. As a conclusion, a new modeling is placed between human and model information generation procedures in order to represent human originated background of model information for engineering objects.**

***Keywords*—Product modeling, model creation processes, human-computer communication, information content based product model.**

I. Introduction

Communication between human and virtual space processes at model based development of products is one of the most actual topics in research and development for engineering. By now, product models have been developed into very complex information structures in order to accommodate information for lifecycle of products. In current product modeling, a main drawback is that representation capability of models is restricted to parameters, structure, and relationships of engineering objects (Fig. 1).

In order to have a general term for all objects those are demanded to be defined during development of products the authors introduced the concept engineering object. Demands for engineering objects are revealed by engineering activities during lifecycle of products.

The main problem arises from a need for modeling beyond the above mentioned capability. Development and application of models of engineering objects in product models must be done in the knowledge of background of the information for those engineering objects. This background was recognized by the authors as information content in [1]. Fig. 1 outlines the proposed change from information to information content at human computer interaction (HCI). In its proposed form, the authors consider information content as the missing link between human and processes for model information. Information content is demanded to be developed for enhanced human-modeling process communication and it is placed in the product model for the application at modification, revision, and relation of engineering objects in product models.

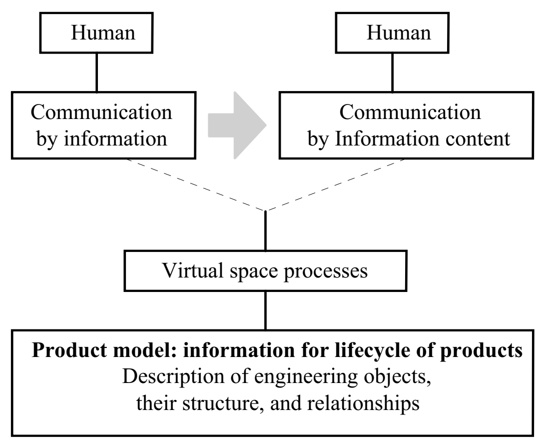

Figure 1. Change from information to information content in product model

Implementation of the proposed modeling in the engineering practice is facilitated by two outstanding achievements. During the last decade of the twentieth century, the International Organization for Standardization (ISO) conducted development of the STEP (Standard for Exchange of Product Model Data), ISO 10303 product model standard that gives an object oriented information modeling background for activities in product modeling and for information loss free interoperability of product modeling systems with between different product models. The other achievement is development of industrial PLM systems in the direction the representation of knowledge for the definition of engineering objects. These formal representations offers media for the communication of control activities from information content modeling.

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In this paper, the authors first introduce trends and results in areas of product model development that are in close connection with the proposed modeling. Following this, virtual space processes are discussed and analyzed for information content based product model where information content serves control of generation of related engineering objects. Next section of this paper discusses essential modeling processes for information content. Finally, implementation of the proposed modeling methodology and processes is prepared by the definition of connection points between the information content modeling extension and the current industrial modeling processes in advanced product lifecycle management (PLM) systems.

II. Trends and Current Results

By now, highly integrated industrial product modeling systems constitute background of engineering applications in all of the competitive industries. Product information is integrated from less or more sources in a consistent product model. Very complex product as a car can be represented in a single virtual space. Consequently, great deal of industrial product and process related research activity has been moved into modeling environments. Because these environments have the capability of complex representation of physical spaces for products, the authors consider them as virtual spaces.

Extensive and sophisticated modeling capabilities in engineering purposed virtual spaces justify the increasing need for intelligent product modeling. Because product model must represent intent of humans, any intelligent content must be relied upon on content from human thinking process, human certificated knowledge, and human experience.

Intelligent capabilities in knowledge related product modeling are expected from research in virtual spaces. The “venue” of this research is a virtual engineering space that represents latest advancements to assist accepting intelligent content. The authors joined to this effort. They analyzed one of the most advanced and comprehensive PLM environment for this purpose. They published their new proposed idea for information content based product modeling in [1], [2], and [3]. Trends and results in areas of product model development in close connection with the proposed modeling are cited in the following.

Above all, recent objective in the development of product modeling is to serve product related engineering activities for entire lifecycle of products. Authors of [4] describe a product information-modeling framework in order to support the full range of PLM information needs. The framework is based on the NIST Core Product Model (CPM) and its extensions. It is intended to capture product, design rationale, assembly, and tolerance information to the full lifecycle. Semantic interoperability with next-generation PLM systems and capture the evolution of products and product families are also considered.

Model based distant engineering activities require knowledge at the application of models because the only available medium for the communication between engineers is product model. Any other communication decreases the effectiveness of product development considering restricted time frame available in short innovation cycles. Recent development concentrate on formal solution that prepares environment for information content based modeling. In [5], a knowledge driven collaborative product development (CPD) system architecture is proposed which will facilitate the provision of knowledge in product development. This work is motivated by a definite need by distance product development for information and knowledge in the place, time and format required.

As it was stated in this paper, human intent must be involved in product model. In [6] issues at capture, representation and retrieval of design intent are discussed, a definition for design intent is presented and a context-based inference system is proposed to capture design intent from model data. Design space is defined on corporation level and design level. Authors of [7] emphasize importance of construction history, parameters, constraints, features and other elements of design intent and suggest implementation of product model data exchange with the preservation of design intent, based on the use of newly published parts of the International Standard ISO 10303 (STEP).

Current industrial product modeling systems offers essential knowledge definition and problem solving modeling capabilities as it is discussed in papers [8] and [9]. Rules define some entities or activities in the modeling process depending on well-defined circumstances. Checks recognize situations with different levels of severity. A reaction reacts to well-defined events by given activities in the modeling process. Parameters relations are reorganized into new categories. Rules, checks, formulas and other relations can be organized into relation sets. Parameters are optimized for minimum, maximum, etc. according to essential or user defined algorithms. An advanced modeling capability facilitates analyses for constraint satisfaction. Design of experiments capability allows for perform virtual experiments among others in order to find interactions between parameters and the most influential parameter.

In recent development of product lifecycle management (PLM) systems, wide range of real time simulations is applied at the definition of engineering objectives and their interrelations. Most important ones are for surface characteristics, completeness of topology in solid shape models, place dependent parameters in solids and surface, placing and movements of parts in mechanisms, functional connections of parts and units, and interaction of humans and products. Currently, knowledge and engineering experience are contained by modeling programs or they are collected from user interface. Main purpose of the information content based modeling as proposed by the authors of this paper is human controlled generation and representing the necessary knowledge and experience within the product model. A higher level of automation towards intelligent model supported engineering activities has been conceptualized.

III. Virtual Space Processes

Establishment of product modeling where information content controls generation of engineering objectives requires new processes in the virtual space in coordination with processes in current PLM systems for the development of product information. Fig. 2 outlines the proposed extended product modeling. Human communicates content for information considering forthcoming engineering object definition. In real product development environments, several humans collaborate so that the task is creation and managing information content resources in order to best collaborative decisions. Information content is mapped to engineering objects in the form of human intent, engineering objective, contextual connection, and decision entities. This content controls information content based modeling processes. These processes control object engine processes at their activity for the generation of model information for related engineering objects.

As an example, a screw engineering object is to be defined by a set of its parameters. Human defines this component for a given function, in the context of a flexibly developed product environment. Function and context are determined by the intent that is developed in the course of thinking process for the screw. Other intent carriers such as standards, previous decisions, instructions, and expert advice are also involved in order to gain a complex human intent definition. Engineering objectives include function, strength, design for minimal weight, electrical conductivity, etc. The above short example shows that very complex information content may be behind a very simple engineering object. When a human coordinates a decision which has effect on this screw, the minimal required background content may contain various things, knowledge and consideration of which may be critical.

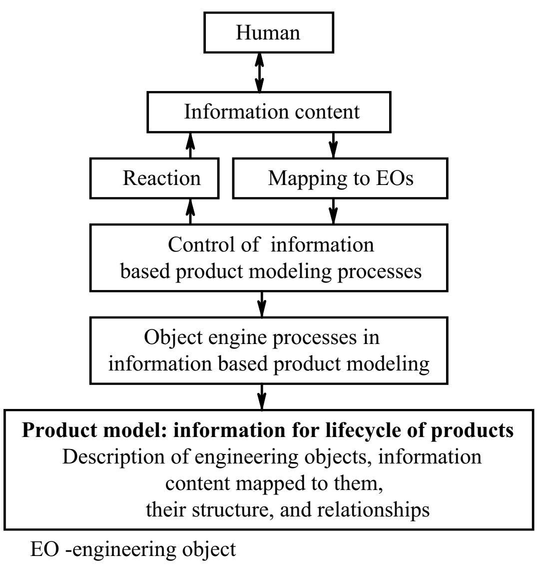


Figure 2. Extension of product model by content

It is inevitable, that model representation for information content is to be developed from human intent. Information content should answer questions how and why, including relations. Process for this is outlined in Fig. 3. Human intent is represented as knowledge and experience. In the meantime, new concepts are defined for the product model as information content. Engineering objectives are defined according to human intent and are represented as behaviors. Context connects behaviors to their model environment or states the originality of engineering object related definitions. Decisions are made for behavior concluded from human intent considering context defined affect chains. It is important that information content modeling does not replace but control the generation process of engineering objects.

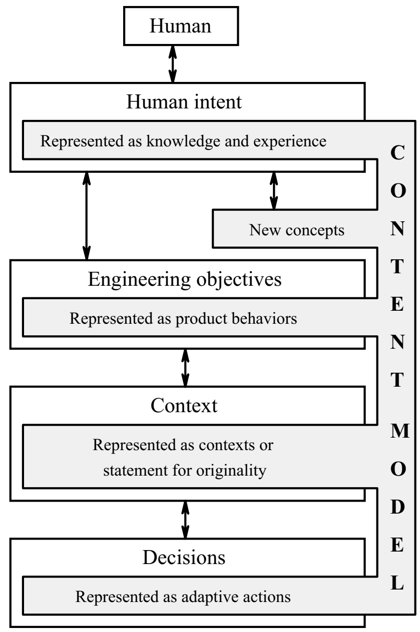


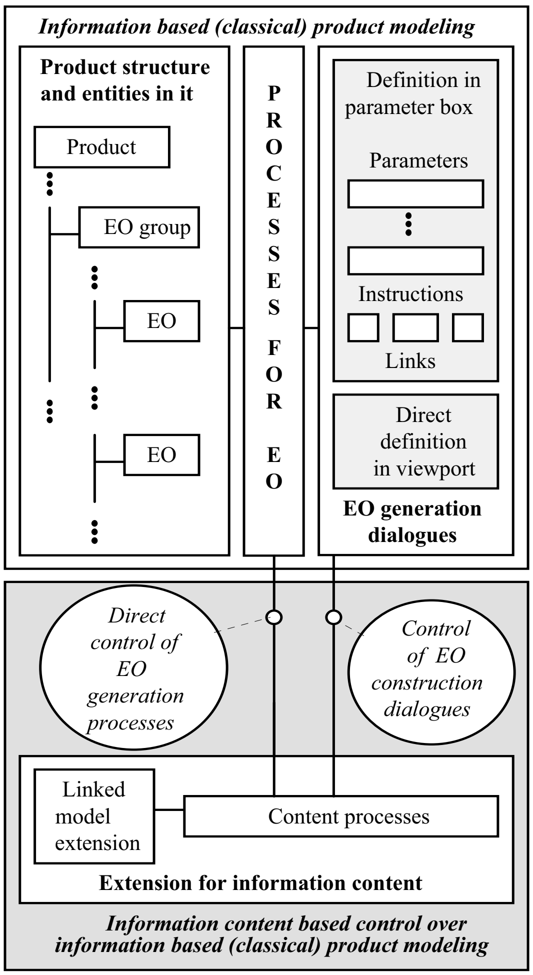
Figure 3. Process and representation for information content

The proposed modeling utilizes strongly contextual nature of product entities. Product modeling started with automated islands for most urgent tasks such as representations of spatial surfaces where mathematical representation and manufacturing of the physical surface by using of this representation at equipment control was not avoidable any more. During the nineties, efforts were started for the integration of these islands and widened automation of engineering activities. The authors analyzed and collected main integration aspects and consideration and synthesized them into a contextual connection system as it will be explainer later in this paper (Fig. 8).

Contextual connection starts from an intent. Intent is used, for example, at the definition of a specification. This specification is applied at the creation component entities for a product such as curves for the generation of surfaces. Surface is generated in the context of these curves. When curves are changed, surface changes accordingly.

Information based product model is considered as classical product model by the authors. Current advanced classical product modeling with potential to accept control from the proposed information content based modeling consist of entities for related engineering objects placed in a product structure, as well as processes and human dialogues for the generation of engineering object, relation and structure entities

(Fig. 4). Information content based product modeling processes may act on classical product modeling directly by control of engineering object generation processes, or indirectly by control of engineering object construction dialogues.



EO -engineering object

Figure 4. Communication of information content with information based product model

IV. Virtual Processes for Information Content

As it was stated above, product model is conceptualized and constructed for lifecycle support of engineering activities in a virtual engineering system. Consequently, information content should be established for this wide application. Te first step for the definition of information content is extracting human intent during thinking process for engineering object definition (Fig. 5). Human mind is supported by some form of information content outside of the computer system. By using of information content from the already decided, existing entities in a product model, human restricts solution spaces for parameters of given engineering objects. In the meantime, elements of thinking process and partial decision points are recorded as components of human intent model. Interim decision points are for behaviors at circumstances, functional relations, and parameter relations. Elements of thinking process are attached to these interim results.

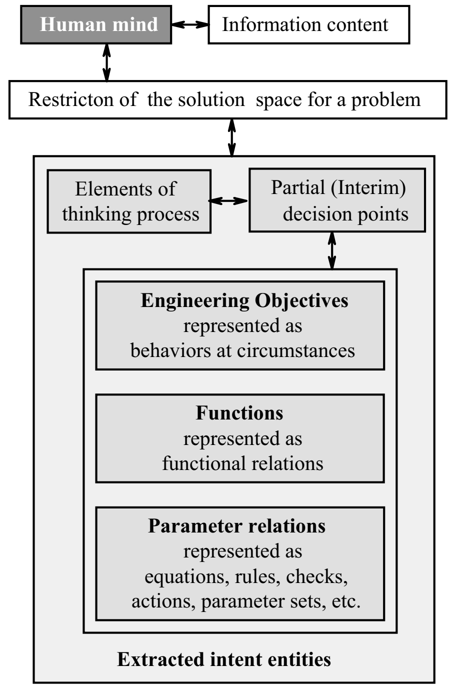
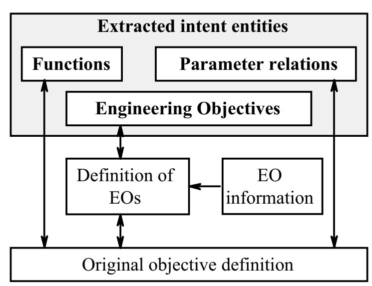


Figure 5. Extracting human intent

Next important statement in the proposed modeling is that ad-hoc solutions those do not consider higher level decisions and circumstances must be excluded during product development. In order to realize this, decisions must be relied upon well-defined engineering objectives considering all affecting contextual connections. For this purpose, the authors extended the classical definition of engineering objectives [3]. Engineering objective comes directly from intent or it is defined as an original one using related intent entities (Fig. 6).



EO -engineering object

Figure 6. Engineering objectives

Product structure is basically contextual because all of the engineering objects are defined in the context of parameters or other engineering objects, and for specifications. Contexts are extracted from contextual engineering objectives and defined for original ones (Fig. 7). Target engineering objects are constrained and contexts are analyzed for contradiction and consistency.

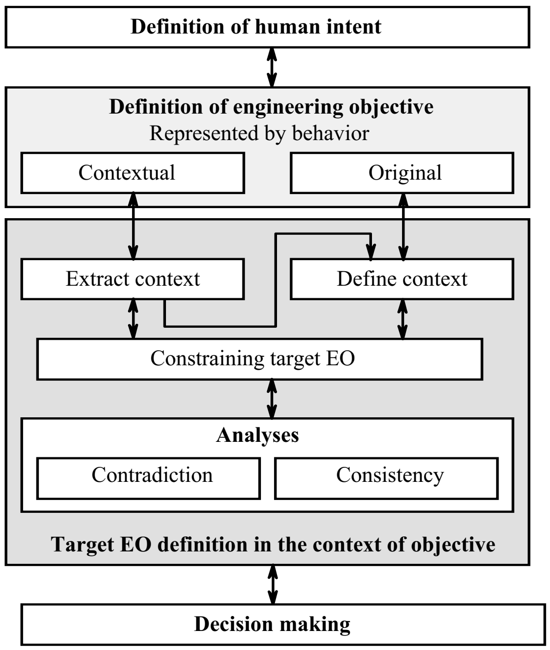


Figure 7. Contextual definition of EOs

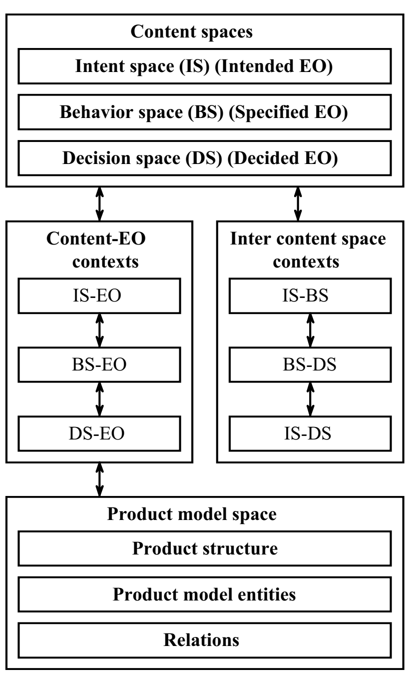


Figure 8. Contextual definition of content entities

Fig. 8 outlines main contextual structure of the proposed extended product model. Information content is organized in three interconnected content spaces. These spaces are intent space, behavior space, and decision space for intended, specified and decided engineering objects, respectively. Relations in the product model are represented by content-engineering object and inter content space types of contexts. Control of product model information in classical product model space is realized through content-engineering object contexts while intents, behaviors, and decisions are interrelated by inter content space contexts.

Decision process coordinates changes for construction, improvement, or correction of existing entities in a product model. For control and analysis of affects of changes, change affect zones are defined for the most influential engineering object parameters as sets of engineering object parameters potentially affected by those engineering objects (Fig. 9). Change chains represent propagation of changes through change affect zones. Actual change attempts are mapped to engineering objects and must be verified by affect analysis. Verified actions are decided for engineering objects. This is the channel to control of parameters describing engineering objects.

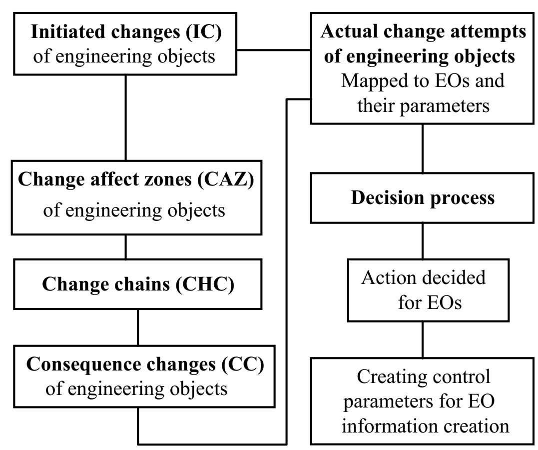


Figure 9. Decision and control of Engineering objects

V. CONTENT CONTROLLED DEFINITION OF ENGINEERING OBJECTS IN PLM SYSTEMS

A critical question for the possibility of implementation of the proposed information content based product model is that how model creation process is controlled during product definition in industrial product lifecycle management (PLM) systems. For the communication between information content and information based modeling processes, open architecture and application programming interface (API) are available in advanced PLM systems. The next question is that where the connection points for control of generation of information based product model entities are. The answer is briefed in Fig. 10.

Recent advancements in knowledge and expert like capabilities are offered by current classical product modeling systems as connection points (Fig. 10). These capabilities are for the representation of relations, as well as for grouping, and parameter definitions.

Relation capabilities include checks to recognize situations and advise modification of model information, rules for generation of engineering object parameter information depending on well-defined situations, and reactions to react events by specified activity. Formulas establish relations amongst engineering object parameters. Actions decided for engineering objects control relation capabilities in order to generate engineering object information. Grouping facilities for the definition of arbitrary sets of parameters and relations help to organize these entities according to engineering objective definitions.

Advanced methods are available for the definition of parameters of engineering objects. Information content can be applied for the control of the related modeling processes. Virtual experiments are planned and executed by performing computations of output parameters in case of different values of input parameters in defined ranges of analyzed parameters. Optimizing parameters is performed by processes considering built-in or user specified algorithms.

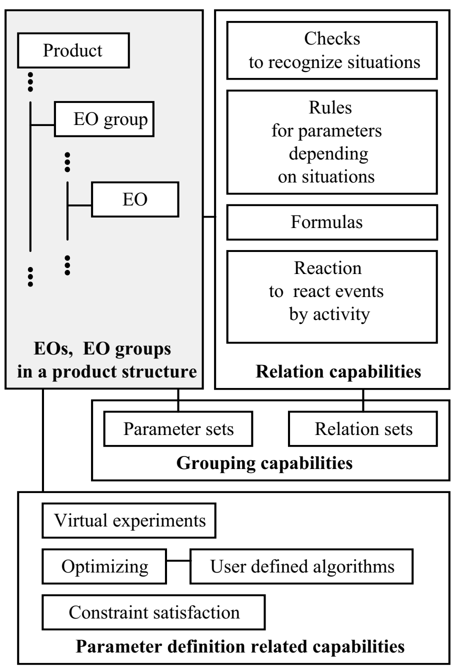


Figure 10. Connection points in classical product modeling

VI. CONCLUSIONS AND FUTURE WORK

Competitive advanced development of product is done in comprehensive industrial modeling and model information management systems where information is generated for related engineering objects. Studying this new style of engineering, the authors recognized high number of engineering objects and their relations as a source of serious problems at survey of an existing model and human intent for subsequent engineering object definition activities. At the same time, the authors recognized that advanced dialogues, possibilities for relating object parameters, and object parameter optimization and other parameter management capabilities offer connection points for the control of generation of engineering objects and their relation by using of the background of model information called as information content. Information content based modeling processes are proposed in this paper. These processes ensure engineering objects to be defined on the basis of human intent. Decision making considers human intent based engineering objectives taking contextual connections into account.

Research in the next future will be focused on content feature definitions and elaboration of generic content features in coordination with information based product model features in industrial product modeling systems.

ACKNOWLEDGMENT

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