An Application Conform Method to Enhance Intelligence at Automation of Product Definition

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Abstract: Engineers have moved into virtual environments during the past decade in leading industries. The primary method is modeling of engineering objects mainly for sophisticated simulation processes in order to bringing product prototype development into virtual environments. Model must serve engineering activities during the lifecycle of products from the first idea to the end of successful recycling. In this new situation, correct modeling and communication for proper and enough information in product model is critical. In this paper, the authors introduce their new approach and method for product modeling where the current prevailing information based product model is extended in order to establish a higher quality of the communication between human and product modeling processes. Paper starts with an outline of functions in product lifecycle management (PLM) systems and a discussion on requirements against definition of engineering objects during development of products in virtual systems. Following this, content of information and possibilities for its modeling is explained as the basic concept by the authors. In the rest of the paper, modeling of human thinking process in engineering activities and human controlled and organized dependencies at decision making are proposed as methods for effective information content based product modeling.

Keywords: Product Lifecycle Management, Model based automation in engineering, Information content based product model, Human-computer interaction, Change management at product development

1 Introduction

Product development utilizes achievements in information science and technology at the description of large product structures, high number of product variants, and arbitrary relationships among engineering objects. Engineering activity can be considered as a complex decision making where decisions are highly interrelated. In the practice of computer integrated engineering, concurrent activity of engineers results huge number or objects and their relationships in large product models. These models can not be handled in conventional modeling environments and need high level and effective automation at decision making. Conventional knowledge based methods have been failed in engineering, The authors analyzed the cause of this situation and recognized a conflict between information content based thinking of engineers and the pure information based modeling processes. The result is an extension to the information based product model in order to better communication between human and modeling processes.

This paper introduces the above mentioned extended product modeling. The authors introduce their new approach and method for product modeling where the current prevailing information based product model is extended in order to establish a higher quality of the communication between human and product modeling processes. Paper starts with an outline of functions in product lifecycle management (PLM) systems and a discussion on requirements against definition of engineering objects during development of products in virtual systems. Following this, content of information and possibilities for its modeling is explained as the basic concept by the authors. In the rest of the paper, modeling of human thinking process in engineering activities and human controlled and organized dependencies at decision making are proposed as methods for effective information content based product modeling.

2 Lifecycle Management of Product Information

Two important recent changes in product development are extension of modeling to the lifecycle of products and integration of engineering functions in product data management (PLM) systems. The scenario is outlined in Figure 1. PLM system supports integrated handling of different models in mechanical, electrical, electronic, computer and other areas of engineering. Collaborative functionality serves communication inside and outside of the PLM system. Influencing humans are in dialogue or indirect communication with modeling. Product modeling serves part and subassembly design, analysis and simulation, manufacturing planning, and programming for control of production equipment. Other important PLM functions are marketing, product support, and recycling. PLM system is more or less integrated with enterprise resource planning and management, company management, and production.

Current product model in a professional industrial system basically consists of a sequence of definitions for engineering objects and their relationships. Term engineering object (EO) may cover among others, a part, a building element of a part, a higher-level element in the product structure, an analysis result, or an element in a manufacturing process structure. Engineering objects are defined in the context of existing engineering objects in order to fulfill product specific engineering objectives.

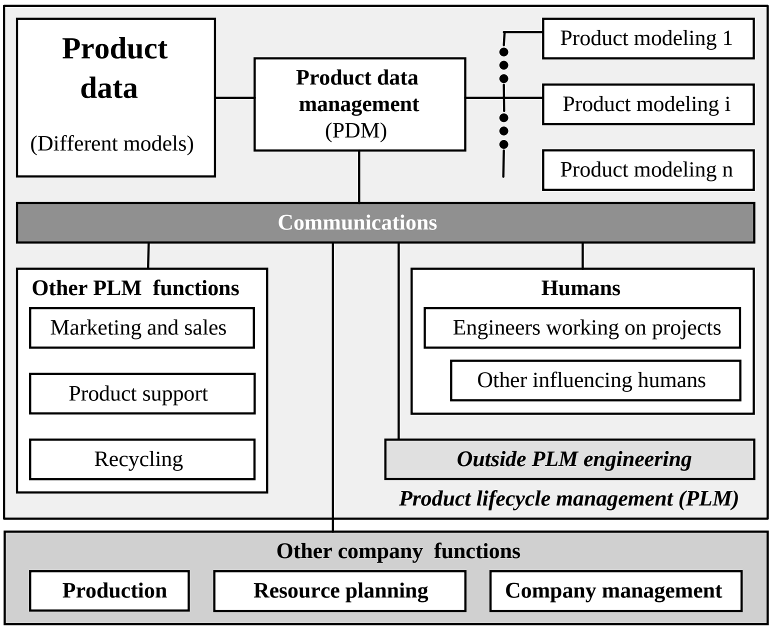

Figure 1
Lifecycle management of product information

Attempts to enhance product models and automation of decisions in this direction by using of sophisticated knowledge representations and knowledge based problem solving methods were not successful. Main cause of this situation is that definition of engineering objects must be done in consideration of extensive requirements. Above all, the main challenge is that information is required about intent of all influencing humans in the model. Evaluation of a model needs information about background of decisions. Support of a decision requires information about other decisions that are in close connection with it because change of an engineering object requires analysis of all affected engineering objects. Relationships amongst engineering objects carry this information. However, tracking of interrelated decisions is impossible in current product models. Some most relevant development efforts to achieve modeling that can fulfill some of the above requirements are cited as follows.

In [1], information model is applied in order to easy identification and analysis of information requirements through process models. 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. In [3], graph and hint based methods, convex hull decomposition, and volume decomposition-recomposition techniques are introduced. 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. Paper

[5] presents the 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. In paper [6], interfacing knowledge oriented tools and computer aided design 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. Paper [7] emphasizes very multi-disciplinary character of work in early stage of the aircraft design. Large variety of specialized tools must be compatible. Otherwise, interface problems are the consequence.

The authors worked on various product modeling problem related projects during the past decade. In order to establish an enhanced human-computer interaction (HCI), they analyzed then modeled human intent [8]. Knowledge that is defined, filtered, and accepted according to human intent is introduced in [9]. Method was published for associative engineering object definition and product behavior analysis driven management of product changes in [10]. The authors introduced the integrated model object as complex model object for closely connected engineering objects [11]. As a preliminary analysis for the integration of the above methods with the methodology of modeling in CAD/CAM systems, the authors of this paper surveyed problem solving techniques available at model-based engineering in [12].

3 Information Content in Product Model

Main purpose of product modeling is to record results of human thinking about a product or interrelated product. In other words, intents of humans are defined in product models. As a consequence of the nature of current product development, intent of high number of humans must be coordinated in a single product model even at the definition of a single engineering object. This is impossible to achieve without modeling of information content as background of decisions on engineering objects.

The currently prevailing information based product model is characterized in Figure 2. The authors of this paper refer this model as classical product model. The challenge depends on the possibility for presence or interaction of human who made the original decision on the engineering object to be modified. Even if an original decision maker is available, additional questions are emerged about the effectiveness of the contribution. As a conclusion, product model must have more or less information content in order to replace some human activities at its application.

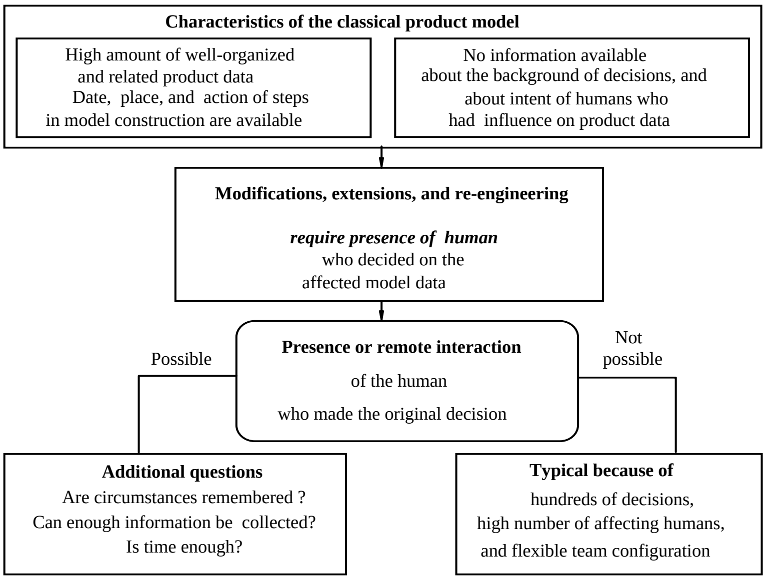

Figure 2
Classical product model

Figure 3 explains a new multilevel information content based product model structure. This model consists of two multilevel structured sectors, one is for restructured information based and the other is for information content based product model. The main essence of this modeling is that human is not forced to convert content of mind into information any more. Instead, critical elements of thinking process for the decisions on engineering objects are recorded in levels of the information content based product model sector. Model creation procedures for the information based model are controlled by using of information content.

Information based sector of product model includes the following content controlled levels (Figure 3). Level *Identifications* includes access information that blocks unauthorized control to engineering objects. *Application data* connects engineering objects to their application in product development, production, product support, marketing, and other company activities. Engineering objects, their attributes, and representations are related in *Associative connections*. *Descriptions* includes definition of engineering objects. Level *Representations* is for shape and other engineering objects.

Levels of the information content based sector of product model are as follows. *Intent of humans* includes intent entities that are defined by influencing humans. *Meaning of a concept* carries information about its background. *Engineering objectives* define objectives as behaviors for situations. Target engineering objects are defined in *context* of other engineering objects. Finally, level *Decisions* includes content for decisions for the purpose of control of engineering object information.

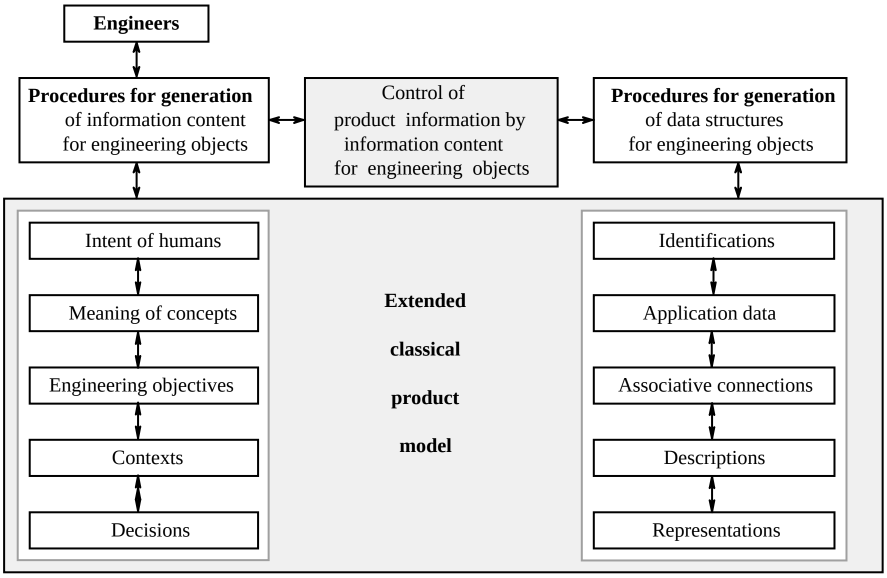

Figure 3
Extension for information content in product model

4 Human Thinking Process in Engineering Activities

Modeling of information content requires recording, relating and representation of some important element from human thinking process. In this section, the main proposed mechanism is presented for acquiring and recording of thinking process elements that are necessary at the application of a model by an engineer who must consider earlier decisions by other engineers.

In order to discover human thinking process, elements and partial decision points of human thinking process have been analyzed (Figure 4). An engineering solution is step-by-step developed in the course of a set of interdependent decisions on relevant engineering objects. Results of thinking process for engineering objects are communicated with relevant model creation procedures.

Human utilizes problem solving methods and procedures and defines and accepts knowledge at each element of the thinking process. Interdependencies with other humans are realized through received and defined constraints. Constraints describe intent of those humans. Constraints have one of the accepted, rejected, argued, and applied states. In case of status applied, the original and the applying decision-makers often share responsibility. Decisions from higher level of hierarchy may be argued when measures in the actual engineering environment allows it.

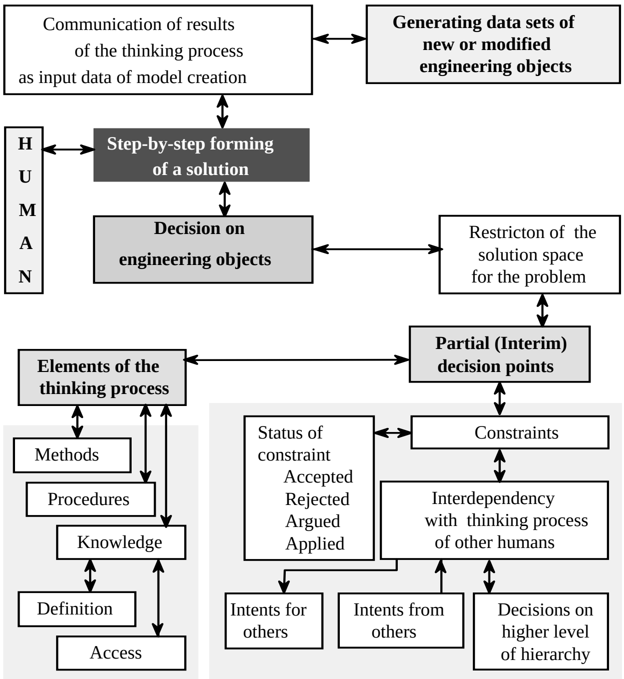

Figure 4
Elements and partial decision points of human thinking process

5 Human Controlled and Organized Dependencies at Decision Making

The main challenge is consideration of a decision as a possible source of change demands for other engineering objects. In the current information based modeling, it is impossible to track the relationships among engineering objects in order to reveal consequences of a decision. This situation generates so much manual work for engineers in product modeling processes. Moreover, interpretation of model information for this purpose is not an effective communication. A method is proposed as a possible contribution to the efforts to solve the above problem.

A new approach to the human controlled autonomous decision making (HCADM) is intended as a primary means of decision-making during the development of an information content based product model (Figure 5). Decisions are under control of authorized and responsible humans who select, accept, or define content for them. Autonomous procedures are able to handle strongly interdependent decisions because content definition and decision process are separated. Humans define information content for coordinated product-wide decision-making (CPDM). CPDM builds change affect zones (CAZ) by using of change chains

(CHC) in order to gain the capability of tracking and coordination of changes. CPDM generates adaptive actions to control engineering objects.

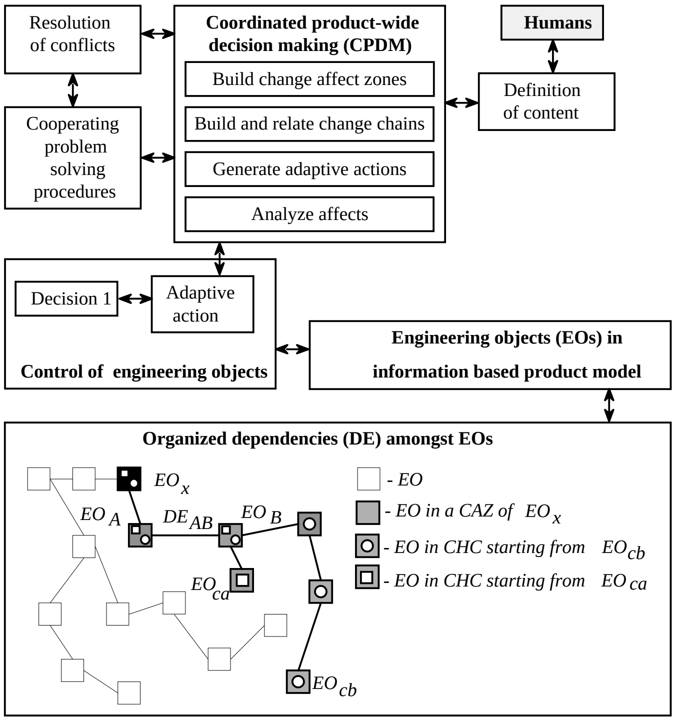

Figure 5

Coordinated human controlled decision making

Role of change affect zone (CAZ) is organized representation of affects by modifications of an engineering object (EO). It discovers routes to all engineering objects that may be or must be modified as a consequence of modification of an engineering object for which that change affect zone is defined (Figure 5). Change affect zones of engineering objects change with modification of the relevant engineering objects during development of a product model. Consequences of changes are propagated along change chains (CHC). Pairs of engineering objects are in contextual or other associative connection. These dependencies are represented in a graph where a node represents an engineering object by its actual parameter or parameter set. An arc represents a dependency. Change affect zone of an engineering object parameter or parameter set defines a restricted search space for consequences of its change in the graph. Node of the graph in Figure 5 carries information for any change chain that crosses that node. Two examples are shown in the change affect zone of EOx. These chains are defined back from the EOca and Eocb to the target EOx.

Conclusions

A new direction for more advanced product modeling has been defined as much more assistance for decision making on engineering objects during product development such as is possible with current information based product modeling. This paper includes a proposal for integrated solution of this challenging problem by the extension of current information based product modeling by model of the information content. In this manner, background information of decisions on engineering objects is available for the engineer who applies a product model and is required to revise or change of earlier decisions and to harmonize earlier decisions with new decisions. The main difference between earlier knowledge based attempts for enhanced computer support of decisions and the proposed method is application of a multilevel content model structure between human and generation of engineering object information.

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