Integrated Modeling for Data Integrity in Product Change Management

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Abstract: In this paper, the authors propose a concept and method for management of changes of engineering objects during integrated modeling of products. The ultimate objective is development of intelligent model objects that include modeled object data and behavior description, and human intent filtered knowledge. The proposed model objects are intelligent organizers of information, knowledge, and procedures for decision assistance. Results facilitate completing present simple data, rule and formula based relating of parameters of modeled objects by an intelligent solution. The paper details application of integrated model object for description of an interrelated group of modeled objects. Description of engineering objects is introduced. Following this, essential management of changes of modeled objects is shown. Next communication of changes in the affect zone of changed objects, is detailed. Finally, implementation of the proposed methodology as an extension of shape centered modeling of products and concept of the extended modeling systems are discussed as implementation issues.

Keywords: Integrated model objects, behaviors of modeled objects, intelligent decision assistance, intent filtered knowledge, shape centered description

1 Introduction

Advanced model based engineering is moved towards huge integrated computer systems where engineering objects and their relationships are described in a system where substantial measures must be done in order to saving data integrity at frequent changes of modeled objects. At the same time, integration makes it possible to apply advanced procedures for the purpose of handling changes. Change to computer controlled manufacturing during the last two decades stimulated development of methods for computer description of shape and other information of parts in computer models. By now, most of parts have shape that cannot be designed and manufactured by conventional engineering methods. The authors studied advanced modeling and recognized the following fundamental contradiction. While engineers are engaged in management of continuous modification of huge interrelated data sets considering high number of affecting factors, and their work is controlled by their own intent and intent of other engineers, decisions are not supported by intelligent computing. At the same time, elementary knowledge as rules and checks, processing interrelated sets of parameters instead of single parameters and other means to receive results of intelligent computing are available. The authors did a research in this area in close connection of intelligent computing and industrially applied advanced modeling. They consider modeling of products consisting of parts as shape centered modeling. The proposed methods are restricted to engineering objects where any other information can be attached to shape information. The objective of the research program is development of intelligent, high-performance model objects that include object data and behavior description, human intent filtered knowledge, as well as model creating, simulation and communication procedures. Knowledge and procedures are mainly accessed from industrial modeling systems and other systems from the engineering environment. The proposed model objects are intelligent organizers of information, knowledge, and procedures providing a powerful assistance for decisions of engineers. Their implementation in open architecture engineering systems contributes to practice oriented application of intelligent computing in engineering. Results facilitate completing present simple data, rule and formula based relating of parameters of modeled objects by an intelligent solution.

The reported research relies on several earlier works of the authors in modeling and coordination of human intent in engineering [1], in general characteristics of intelligent model objects for description of engineering objects [2], and extending the feature principle to modeling of behaviors of engineering objects and adaptive actions for proposed or enforced modification of interrelated model entities [3]. Adaptive actions are generated by adaptive modeling procedures. It is defined as an entity that carries information about an attempt to a controlled change as a result of a decision during modeling. Two earlier works are cited by references [5] and [6] from the field of intelligent agents for interactive simulation environments and feature based parametric CAD/CAM. One of the main purposes of virtual systems is providing information for optimal control of equipment. Authors of [8] reported a method that offers possibilities for integration in this direction. Advancements in application of computer systems for engineering purposes are stimulated by advancements in the area of digital computer principles [9]. They served as preliminary concepts for the reported work.

The paper introduces methods by the authors for application of computer intelligence in change management during model based engineering procedures. The reported work utilizes recent modeling technology of shape-centered engineering. The paper details application of integrated model object for description of an interrelated group of modeled objects. Description of engineering objects is introduced. Following this, essential management of changes of modeled objects is shown. Next communication of changes in the affect zone of changed objects is detailed. Finally, implementation of the proposed methodology as an extension of shape centered modeling of products and concept of the extended modeling systems are discussed as implementation issues.

2 Description of Engineering Objects

Integrated model object describes engineering objects and manages communications and information exchange with the outside world [2]. Information to be handled about modeled objects in an integrated model object is outlined in Fig. 1. Modeled objects are described by their characteristics including elements, composition and relating of elements, behaviors, procedures for processing, knowledge, and actions.

Communication links data, knowledge, procedures, actions, history, and on-going events to each modeled object. Humans having restricted responsibilities and authorities control the model object. Outside world is connected by information exchange. One of the purposes of this paper is an analysis of application of the above detailed general schema. Intelligent content of model is included and handled by coordinated application of knowledge descriptions, behavior definitions, and adaptive actions.

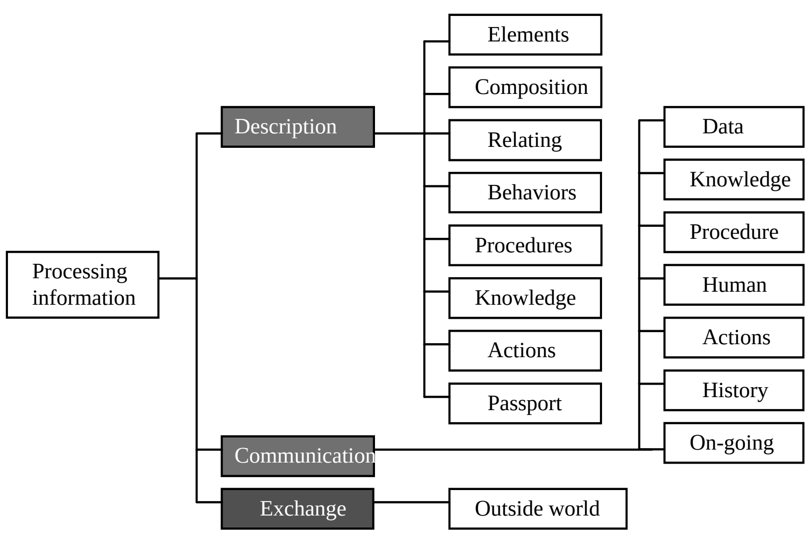

Figure 1
Stored, communicated, and exchanged information

3 Essential Management of Changes

Engineering objectives are defined as behaviors. The authors proposed behavior driven evaluation of effects of changes before propagation of changes along chains of associative connections of parameters of modeled objects is decided. Modeled object is characterized by several behaviors according to its content. It is assumed that any change of an object at its development and other modification may affect one or more behaviors. Consequently, changes of an object and other objects in its affect zone may require repeated evaluation of behaviors. If a change modifies situations defined for behaviors, behaviors are undergone repeated evaluation. Because behavior represents design objective in itself, specification of behaviors may be also changed. This is why reverse of the above process is also applied.

Basically, integrated model objects involve parameters, behaviors, associativities, knowledge, and adaptive actions. These rely on definitions of engineering objects, data descriptions, solutions, situations, circumstances, and procedures. Suppose that a model object describes interrelated modeled objects at a moment during an engineering process. Development, variant creation, and correction actions by engineers involved in the engineering process as well as other engineers are considered as changes. This approach is proposed in order to establish a unified management of computer intelligence supported engineering processes. Powerful but not intelligent change management is available in industrial modeling (e. g. CAD/CAM) systems to accept the proposed procedures as connected ones.

Management of intelligent processing of changes can be followed in Fig. 2. The system receives information about accepted and proposed changes from interfaced humans and outside world. Changes are mapped as conditional adaptive actions then their effects are analyzed. The consequence may be directly calculated changes of elementary or composition object descriptions using associativities and change of behaviors. Sometimes a simple change can be defined by associativities but it must be abandoned using changes of behaviors as revealed by effect analysis. Effect analysis may generate additional changes. These changes are analyzed as new change information. Accepted decisions are considered as final adaptive actions. Inside changes are executed while outside changes are proposed. Change attempts are accepted or rejected by the outside word. At the same time, new changes may be generated there.

Approach to change management by the authors is also aimed to support integration of analyses in recent modeling systems. There is a question that how this process will converge towards a final result. The right answer is that the process is under control of humans. Intelligent system visualizes consequences and allowed directions of new and new changes. At the same time, humans define knowledge, associativities, and behaviors. The intelligent system acts as an advanced navigator and not as design automata. In an environment like this, engineers have much more chance than in conventional modeling to find a conflict free solution.

Present style of engineering is characterized by continuous development of products, manufacturing processes as well as sales and other enterprise management related activities. Result of an engineering process at a moment is valid only for a variant, a version, etc. of a product. Continued changes encounter for new or improved products and variants. The above-discussed components are enough to a formal definition and establish of intelligent model objects. At the same time, the manner of model object development in which modeled objects and knowledge related to it build simultaneously, necessitates application of model objects created during engineering activities instead of predefined model objects.

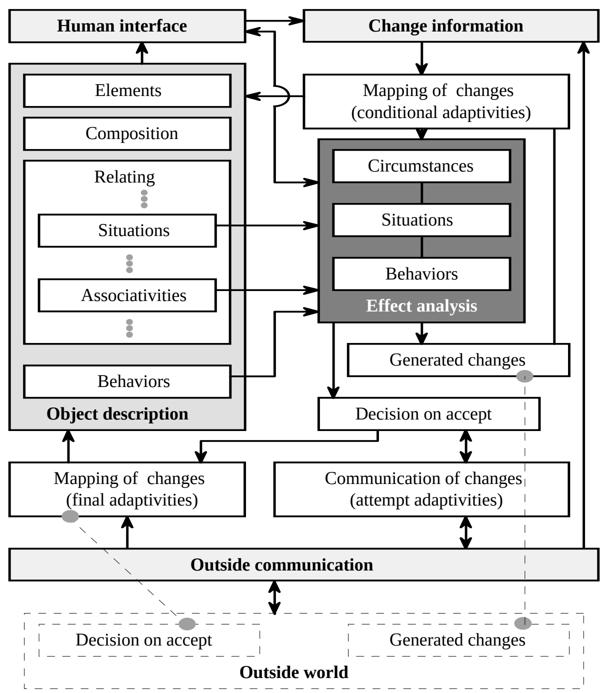

Figure 2

Schema of handling of changes

4 Communication of Changes in the Affect Zone

Flexibility of engineering design, provided by modeling, supports change management. However, a great deal of consequences of modifications of modeled engineering objects must be handled where powerful and efficient assistance of human decisions is aimed. Fortunately, the proposed integrated model object describes interrelated modeled objects including outside of a modeling environment. This was enforced by concentration of modeling systems in global engineering systems, in extended enterprises, encouraging the authors in an extension of their analyses to outside connections of modeling environment established by an integrated model object. The objects to which a modeled object has any effect are considered to be in the affect zone of that modeled object. Model object as defined by the authors includes representations for a given set of modeled objects. Any other objects in the affect zone of these objects must be accessed in the world outside of the model object. Despite efforts to models standardized by reference models and application protocols, incompatible models even not modeled objects are to be interfaced.

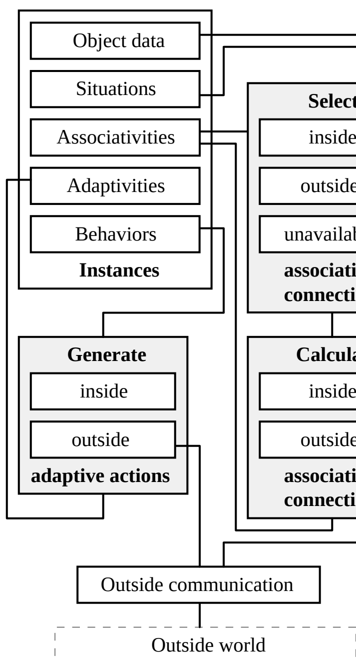

Figure 3

Communication of changes of engineering objects

Communication initiated by change information is intended to be a contribution to solve the above problem (Fig. 3). By using of generic object descriptions, instances of descriptive object entities, situations, associativities, adaptive actions and bahaviors are calculated. Objects, circumstances, and situations are identified using change information. Using associativity definitions and the above-identified entities, inside, outside and unavailable associativities are selected. Unknown associativities cannot be considered by the intelligent processing, they remain to the human who controls the actual engineering process. Following this, inside and outside associativities are calculated and adaptive actions are generated using calculated associativities and behaviors. Effect analysis is done simultaneously (Fig. 2).

5 Engineer Intent Filtered Knowledge

Decision is controlled by combined intent of humans engaged in a decision. The authors emphasize the personal intent nature of knowledge at engineering in [1]. Simple decisions may have complex human background. For example, decision on a single dimension by an engineer who is responsible for it may apply knowledge also from scientists, standards, legislation, local instructions, decisions of engineers on a higher level of hierarchy, and customer demands. Engineers and other humans participating in these decision chains apply high amount of knowledge collected from other sources through a filtering of personal, corporate or even official intent.

Decision support and its background are outlined in Fig. 4. Decisions are supported by three basic methods. They are analysis of behaviors of modeled engineering objects, views created from the related product data, and considering combination of intents of engineers and other humans. Human knowledge sources and outside links to knowledge are applied to complete inside knowledge information. Knowledge items in conventional knowledge base are extended by situations for behavior analysis, typical combined intents to assist combining intents, effectivity to make views, and type of effects as rule, check, etc. In addition, human and outside knowledge link info is included.

Group work of engineers is supported by collaborative software functions. This functionality is applied in close connection with product data management. The authors are studying the possibilities to connect authorization to design intent based decision assistance.

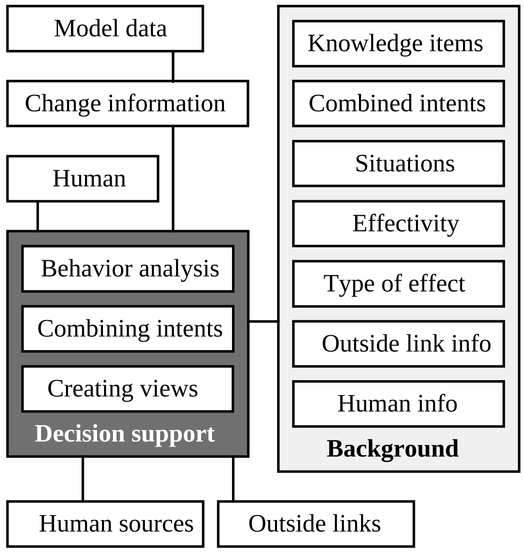

Figure 4
An outline of decision assistance

Presently prevailing shape modeling method is boundary representation where topological entities connect curves and surfaces in the boundary of a shape. Curves and surfaces, in other words geometrical entities, and form features pointed to them are related to describe information about fixed and moving connections of parts in structural units. This is made possible by composition of products using the above units according to standardized application protocols (ISO 13303) [7]. Non-shape related information as materials, loads, manufacturing processes, marketing, etc. has been integrated with shape information in complex product models. The authors proposed control of change management in this structure. A preliminary of this work was published in [4].

Fig. 5 shows logical connections between entities of shape models in recent industrial modeling and entities in the proposed description of modeled objects. Part model entities act as elements in description of a modeled object. Relating geometric or form feature entities of parts in structural units (assemblies) and mechanisms for relative placing of parts and movement definitions by degrees of freedom between them, accordingly, serves as composition information. Relating attributes of shape and non-shape model entities by equations, rules, and, checks are utilized in associativity definitions for intelligent processing.

6 Shape Centered Description

Mechanical parts compose most of products. Sophisticated shape models have been developed for computer controlled manufacturing of surfaces defined in boundaries of parts. Fortunately, most of other product information can be attached to shape descriptions. This offers a great possibility to implement the proposed intelligent decision assistance in shape modeling.

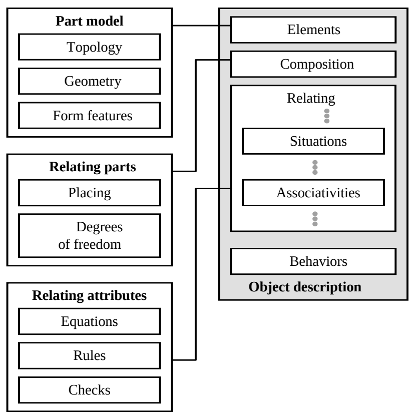

Figure 5

Essential structure of shape centered model

7 Implementation

Implementation of the proposed change management in intelligent model object is considered as an extension to an engineering system composed by existing purposeful professional modeling, product data management, collaboration, and Internet portal software (Fig. 6).

Main advantages of integration of intelligent modeling as an extension are affordable system development, work in actual and proven engineering environment, and application of existing product data systems. Industrial professional engineering modeling system considered by the authors consists of a comprehensive set of modeling procedures, model database with product data management (PDM), user interface, and Internet based group work procedures. Application programming interface (API) serves development of the extension to the system by new programs written in own development environment of the modeling system or by using of other software development environments. The proposed modeling is under implementation in an experimental environment according to Fig. 6. Important section of experiments will be an analysis of model representation capability of the proposed method.

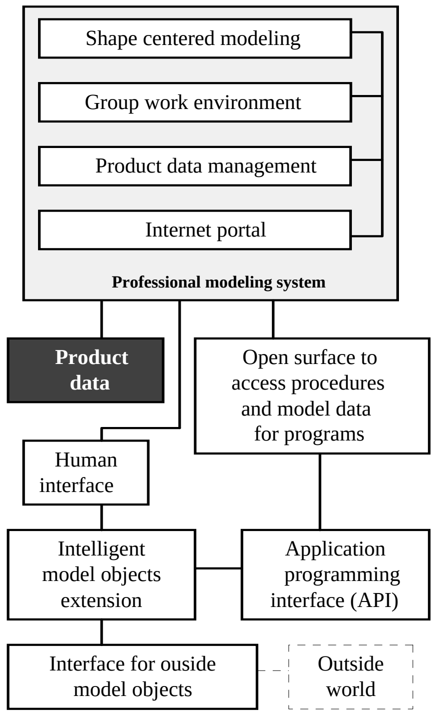

Figure 6
Extended modeling system

Conclusions

Change management is proposed in integrated model object for organized processing of changes of closely connected engineering objects. In case of shape centered models, as mechanical units and products consisting of mechanical units, most of the information about engineering objects can be integrated with shape information. This paper focuses on description and change of information about engineering objects. Content of modeled object information, management of behavior analysis and adaptive change actions, configuration of change affect zone by associative entities, and intent filtered nature of knowledge are discussed. The proposed methodology can be used at decision support as an extension of decision assistance in industrial modeling systems. Future research is planned to establish a pilot system in which virtual experiments answer the suitability of the method in complicated situations at decisions. Nevertheless, the main area of application of the proposed method is decisions with complex information and knowledge background. Conflict resolution by humans, who are assisted by the advanced intelligent navigation, is made easier by the proposed methodology.

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