Mutual Effects of Modeled Engineering Objects and Their Environment

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Abstract: – Design, analysis, manufacturing and production Engineering processes in extensive computer systems are featured by simultaneous creating and modification of high number of various engineering objects. Consequence of modification of one of the modeled objects is modification of one or more modeled objects. Authorized engineers do not agree sometimes modification of some model objects. This situation made changes in an engineering system difficult. Fortunately, associative engineering modeling offers solution for this problem. The authors in this paper propose environment adaptive model objects for tracking the effects of modification of an existing object or definition of a new object on the basis of existing objects. The necessary modifications are enforced or cancelled. In other words, the modeling system analyses all consequences of a modification in an integrated model. To do this, the proposed objects have the capability of description of mutual effects of a modeled object and objects in its environment. They carry and interpret knowledge necessary for revision of earlier decisions. This paper is organized as follows. A general approach to handle intelligence related information in engineering modeling systems. Following this, mutual effects of modeled objects and their environment are explained. Next internal Relationships of a model object are detailed. Finally, application of human intent description for adaptive procedures is discussed and an intent, behavior and adaptivity based change management is proposed.

Keywords: — product model, behavior based modeling, associative models, environment-adaptive models, design intent.

1 Introduction

High number of product variants, special requirements for product items from sales department and continuous development of product have made modification of existing product designs and production plans for a continuous activity of engineers. Modified functional or application requirements for changed customer demands or new product variants need new or modified parts and assembly structures. In conventional modeling, modification is time consuming, tedious work even for experienced engineers. Development product with high number of variants does not assign enough time for the obsolete style of computer aided engineering design where manual modifications are assisted only by several constraint definitions. Engineers who are responsible for some parts, assemblies and other structural units of mechanical products, are often not present at the integration of those units in the final product where modification of those parts is unavoidable. An intelligent modeling is necessary, where intent of engineers is applied at later modification of models.

The authors made analyses to establish a general solution for modeling in the above outlined dynamic environment. They proposed the application of environment adaptive model objects. These objects represent knowledge, experience, and decision making process of an engineer at a remote place. They generate modifications of other model objects in their environment and, at the same time they accept modifications initiated by other model objects.

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 [1]. 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 [2]. 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 [3]. Other preliminaries of the reported work were research projects by the authors in recent years. They analyzed modeling of manufacturing processes and proposed a multilevel model with Petri net representations for process entities [4]. Role of constraints in modeling of automatic shape generation was discussed in [5]. The research reported in this paper have been grounded by activities for modeling and model communication of design intent [6], for integration of feature based models by associativities and constraints [7] and for the application of intelligent computer methods in behavior based engineering modeling [8].

In the proposed system, intelligent model objects initiate communication events with and accept communication events from external entities in a distributed system. Benefits of the method can be summarized as well-prepared model that represents not only engineering objects, but also knowledge of engineers who created them in order to their application in dynamic modeling environments. The proposed model objects can modify their environments according to intent definitions and calculations by the engineer who made the original decisions about the modeled objects. At the same time, model objects can be modified by their environment to harmonize them with related model objects in an extent allowed by modeled information and knowledge.

This paper is organized as follows. A general approach to handle intelligence related information in engineering modeling systems. Following this, mutual effects of modeled objects and their environment are explained. Next internal Relationships of a model object are detailed. Finally, application of human intent description for adaptive procedures is discussed and an intent, behavior and adaptivity based change management is proposed.

2 A General Approach to Handle of Intelligence in Engineering Modeling

The authors concluded model objects with the capability of processing knowledge as solutions for engineering procedures where continuous development and high number of variants results extensive modifications through the product innovation cycle. The proposed model objects are intended to be prepared for self adaptivity and two way adaptivity in their environment. Adaptivity relies on computer analysis of behaviors of the modeled product, in real situations. Adaptive actions are initiated by changes in modeled and related engineering objects. Complexity of engineering modeling system, substantial distance between sites of creation and application of the same model, multi-intent nature of engineering decisions and other characteristics of the product modeling were considered.

The product model concept covers a less or more complex model, having the capability of representation all objects and object relations, demanded by the product related engineering activities from the first idea to the recycling of used products. The authors considered a product model for their analyses as restricted to partial models essential for design, analysis, and manufacturing of mechanical products (Fig. 1).

Fig. 2 summarizes the basic concept of the proposed modeling. *Human A* makes a decision using an *engineering modeling system.* Design intent modeling creates background information and places it in *intelligent model object A.* Then *model object A* is exchanged with or accessed by other *engineering modeling system.* This s*ystem* applies the *intelligent model object A* at decisions during creation the conventional or intelligent *model description B. Model object A* represents *human A* at decisions of *human B.* At the same time, revision of decisions for object *A* may be initiated by object *B*. Supposing that *intelligent model object A* is created in an environment-adaptive intelligent model object, it initiates information acquisition in its new environment and, if necessary, make attempts for changes of its new environment as an agent. Otherwise, it is a passive model description utilized at decisions in the receiving *modeling system*. Source of information and knowledge for the *intelligent model object* is unrestricted because links can be defined for Internet connection.

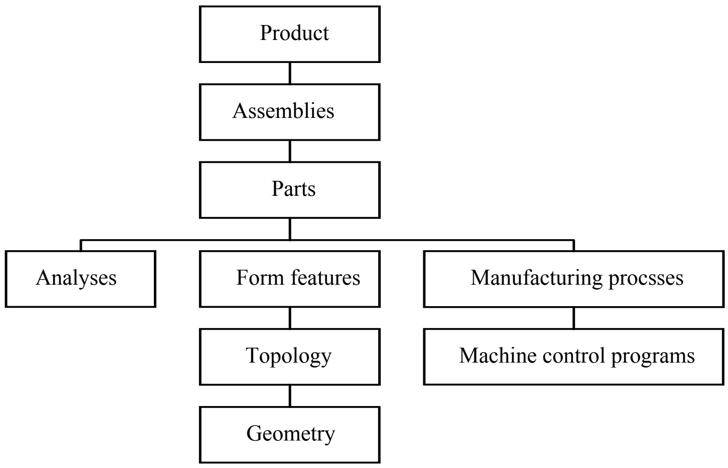

Fig. 1
Essential entities in a product model

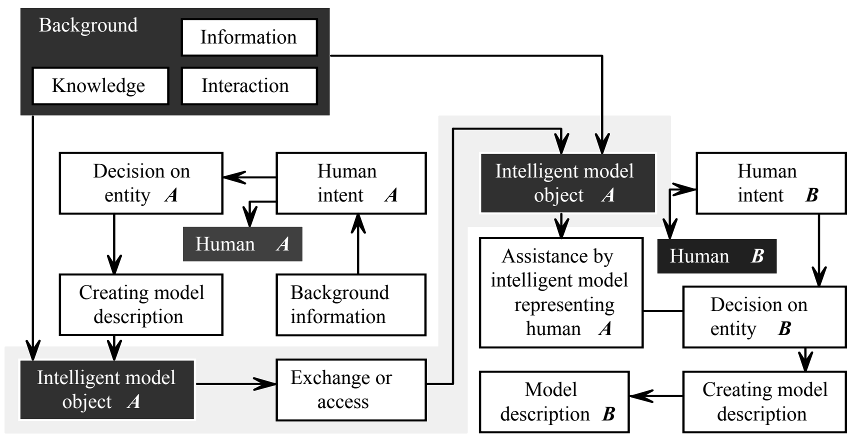

Fig. 2
Intelligent communication of engineering workstations

Essential structure of an intelligent model object can be followed in Fig 3. Conventional model is represented by description of component entities, their structures, and object and entity level attributes. Modification of this model is initiated by outside and inside effects. At the same time, modifications of other model objects are initiated directly by the modification, or indirectly by the application of knowledge built in the object. Inside and outside model entities, their structures and attributes are interconnected by associativity definitions.

Knowledge assists at creation of self and outside modification actions and at evaluation of modification attempts from outside. Knowledge can be structured according to modeled objects related behavior definitions. Permissions control communication and adaptive actions and effects. Main change definitions of a model object and the model objects related to it are modification of entities, reordering of structures, definition of new entity, structure and attribute instance, launch of new entity, structure and attribute definition. They initiate evaluation and adaptivity procedures.

Procedures for processing of information are built in the model object or accessed from its outside world. Model objects in the environment of the model object accept the communicated active model object and offer procedures for processing the information built in the model object. As an alternative, model object communicate its environment by using of special built-in procedures. If the receiving environment cannot offer procedures or the model object cannot activate built-in or accessed procedures, user interface procedures turn to the engineer for intervention at the receiving modeling system. In this case the modeling is done similarly to as in conventional modeling systems.

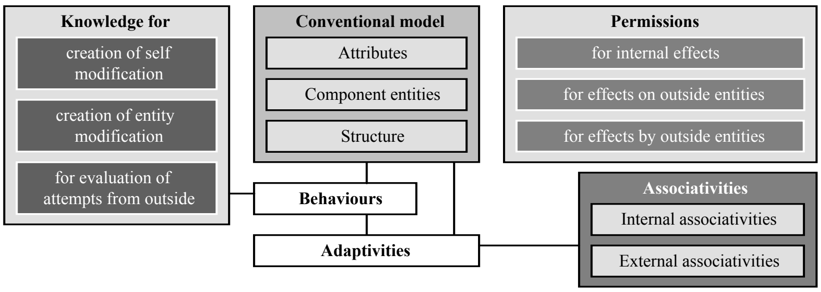

Figure 3
Structure of the proposed model object

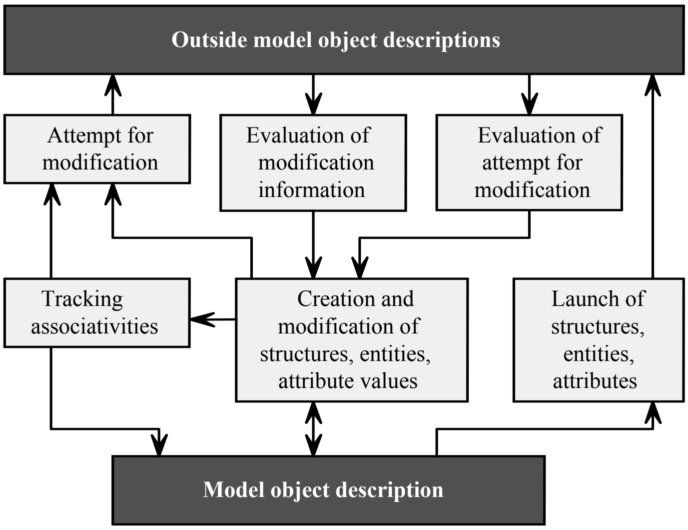

Figure 4
Adaptive procedures

Fig. 4 shows adaptive procedures for the communication of the proposed model object and other model objects. Functions are defined for the purpose of interoperability amongst the actual and other model object descriptions. One of the most important functions is launching new model entities, entity structures and attributes for the new environment. Intelligent model object initiates modification of outside model objects and, at the same time, it evaluates information and attempts for modification coming from outside model objects. Associativities are tracked to propagate modifications to other related entities. If associativity is defined as a constraint, the propagation is compulsory.

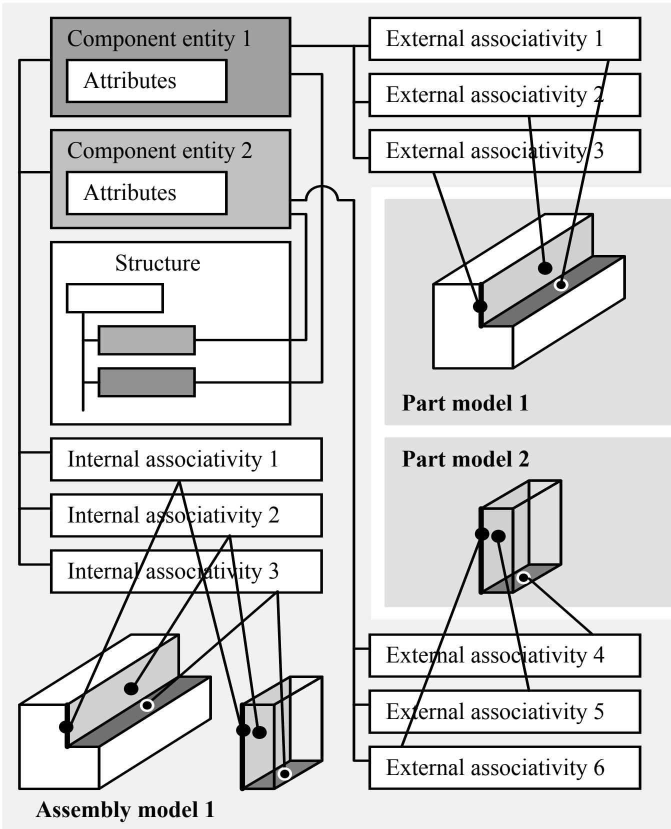

Figure 5
Associativity definitions in a mechanical structure

Internal associativities are defined within the actual model object. External associativities are defined between the actual model object and an outside model object. Fig. 5 explains associativities and their interconnections by the well-known example of mechanical assembly. Three model objects are defined for the engineering objects: *Assembly 1*, *Part 1* and *Part 2*. Parts are placed in *Assembly 1*. Model object *Assembly model 1* includes entities *Component entity 1*, *Component entity 2* and *Structure* as well as *three internal* and *six external* associativity definitions. Internal associativity definitions relate component entities in the structure by the definition of part placing. External associativities relate component entities with part models to access geometric model information for part placing. Part models are not detailed in Fig. 5.

Intelligent model objects need knowledge based processing using some methods from intelligent computing. This paper does not explain integration of rule based, neural networked, Petri net, Fuzzy logic and genetic algorithm based and other appropriate procedures from intelligent computing. Availability of suitable software for flexible application is assumed. However, selection and interfacing of intelligent computing is considered by the authors as one of important issues in the next future research.

3 Environmental Effects on Model Objects

Associative model object is based on definition of its environment. All other model objects that have been or can be related to it during adaptive activities constitute its environment. Stand-alone model objects are also considered as exceptions. Any model object is considered as includable in the environment of a model object that has entities, structures and attributes that needs any consideration of some other entities, structures and attributes of that object and vica.

Typical examples for model objects acting as environment of an other model object are shown in Fig. 6. Two assemblies are related by a dimension of the same value ($l_A=l_B$). Diameter of a hole D_A in a part must be equal to outside diameter d_B on the mating part in an assembly. Tolerance specification is also to be taken into consideration. Part *B* has been replaced by the newly developed part *C*. Part *A* has been changed to accept the new part with changed dimension at the mating surfaces.

Changes of the environment of a model object have different states of effect on model objects such as prescribed, essential, to be considered or indifferent. Status of the effect is defined according to needs of the engineering task. It is important because a change demand with weak status of effect can be neglected to accept change demand with stronger status. Status *prescribed* refers for an effect that always works because it is evident, as in case of examples in Fig. 6, and it is based on a law or standard, etc. Effect in case of status *essential* allows decision for the related engineers who prepare the model object to do this. Status to be *considered* means serious task at change definitions within the model object because decision can not be done on the basis of simple evaluation of circumstances. Often interactive intervention of engineers is required and a display surface should be provided for the engineer who communicates an active model object at a remote computer. Choice of states can be defined according to needs of applications.

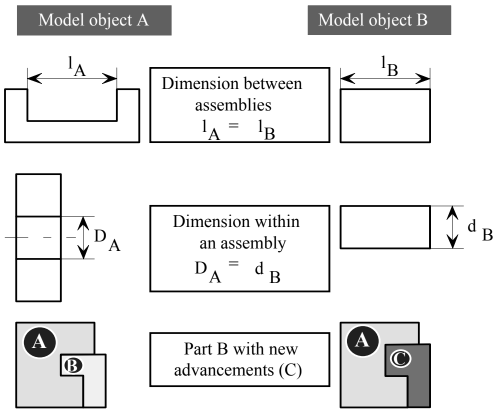

Figure 6

Associative connections of model objects

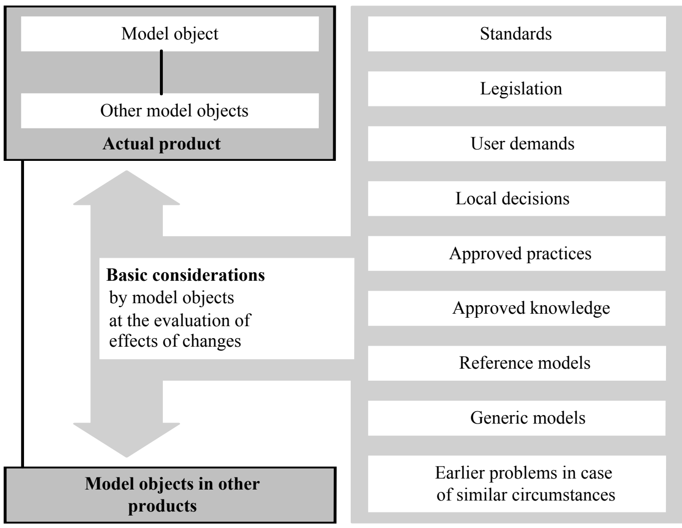

Figure 7

Factors for the evaluation of effect of changes

A model object receives information on modification of other objects and attempts for its modification by other objects of the same or other product model. Evaluation of effects of modification requires several engineering practice specific issues to take into consideration (Fig. 7). The issues in Fig. 7 are listed in a sequence of decreasing strength. Design must agree with standards and legislations. User demands are to be followed because it is the basis of the quality except for demands in contradiction with one of stronger issue. Local decisions can overwrite approved practices. New user demands may require development or application of new practice. Approved knowledge assists decisions taking into account stronger issues. Reference and generic models carry generalized model information and they are specialized according to issues of higher strength. At last but not the least, solutions for earlier problems with same or similar circumstances can help at decision when the engineers responsible for it are helpless. It is perhaps the most useful assistance for engineers and a bank of proved solutions could be collected.

Model objects are related by associativity information between structures, component entities and attributes as it explained on Fig. 5. Clear structure of associativities is established by relating component entities and attributes through structures (Fig. 8). Structure organizes associativity definitions between attributes and component entities. An associativity definition may consist of a logical value as equal or less than, a numerical value for a numerical operation, an equation, rule, or even a procedure for calculation value of the related attribute.

4 Internal Relationships of a Model Object

The proposed modeling involves model representation that describes behavior of modeled objects for various circumstances. Situations based on series of circumstances are analyzed. Intelligent model object receives input effects and creates output effects. Internal relationships and functions serve processing of these effects. Behaviors of the modeled object are elaborated by using of circumstances. A behavior is defined for different situations. A situation is composed by several circumstances. Circumstances are defined by using of elementary functions, responses, and actions. Circumstances and situations organize behavior-based knowledge.

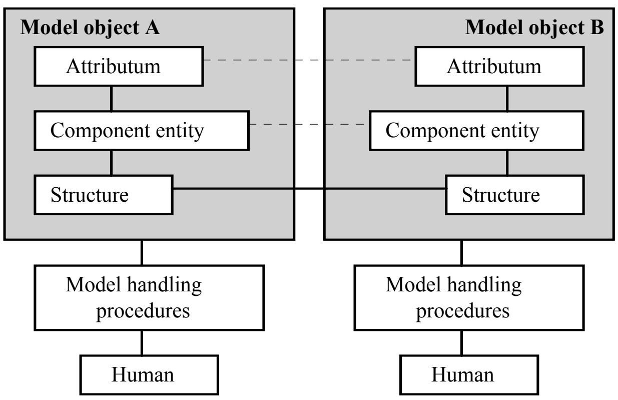

Figure 8
Communication between two model objects

Key functional element of an intelligent model object is situation handling. It coordinates effects, structures and behaviors (Fig. 9). Component entities and attributes are reached via structures by the help of associativity definitions. Objects in the world outside of the actual object produce input effects and receive output effects through a communication surface. Situation handling identifies circumstances, sets the situation and produces reactive behavior. Structure, component entities and attributes are changed according to decision by situation handling based on behavior analysis.

5 Intent Description for Adaptivity

Source of design modifications is new or changed design intent. Intent information is related to decisions regarding characteristics, elements, structure, and attributes of the modeled product object. Intent can be active or descriptive (Fig. 10). Active intent is applied at decision making so that it should be available previously. Passive intent is only a record of a decision as in the case of conventional models. Human defines intent on the basis of a recent decision. A typical passive intent description is explanation in expert system.

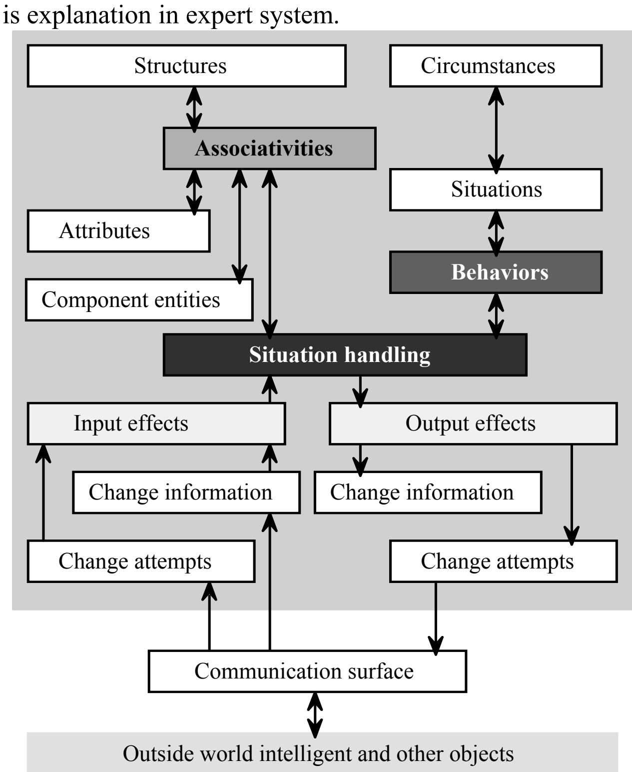

Figure 9
Mechanism of change handling

In Fig. 10, dimension *b* on *Part A* depends on version number of *Part C*. On the other hand, version number of *Part C* depends on version number of *Part B*. Intent definition describes conditions for different versions of a product. There are means for the purpose of creation version information in a single model in recent modeling systems. However complex version related information and background of creation of versions require the powerful tool of intent modeling. Design intent defined application of knowledge provides more or less filtering. Effectiveness of filtering depends on refinement of intent model. Well-organized background information processing assists new or modified decisions by relevant, accepted and proved knowledge.

Environment adaptive model object initiates self and environment related modifications using built in or remote accessed knowledge. Similarly, it is able to accept, reject, or propagate modifications initiated by its environment. This approach has been proposed by the authors to establish an absolute dynamic modeling environment required by recent style of model based industrial engineering design. Main structure of an environment adaptive model object is shown in Fig. 11. Basic components of engineering model object are involved as entities, their structures, attributes, and relationships. These elements carry results of decisions. Intent manager handles intents.

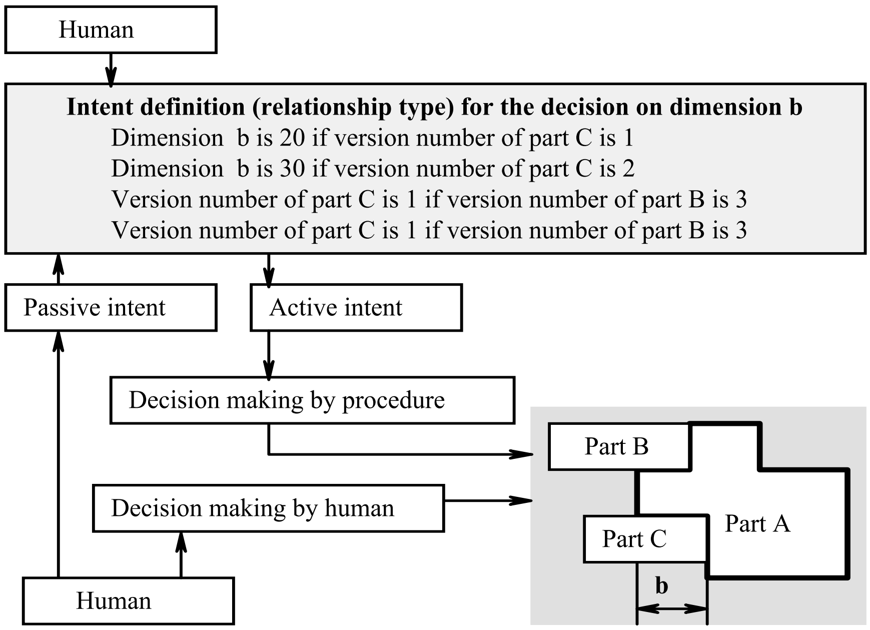

Figure 10
Active and passive intent

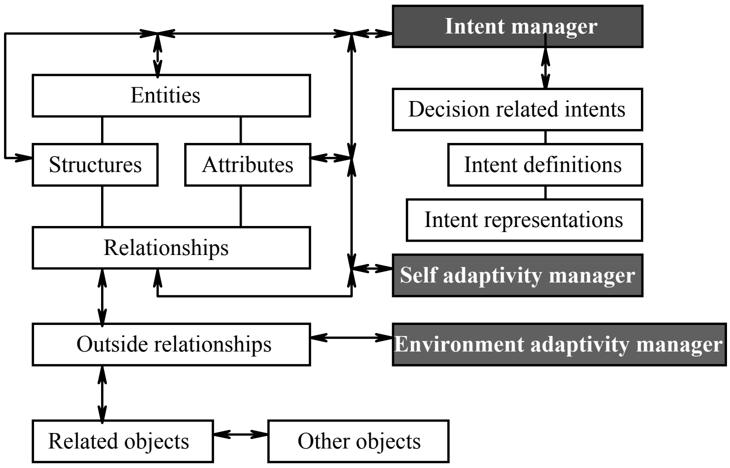

Figure 11
Managers in a model object

Conclusions

Design and manufacturing plan change intensive engineering can make the advance of associative and behavior based modeling. The authors concluded application of complex model objects with intelligent content for behavior analysis and associativities for adaptivity capabilities to solve change related problems in complex engineering tasks. They proposed a concept, approach and method for environment adaptive model object. These model objects are aimed to be suitable as intelligent computer representations in distributed systems. Effects of changes in an actual model object and in other model objects in its environment are analyzed in a behavior-based system. Behaviors are identified by using of circumstances and situations. Complex activity of situation handling has been outlined for the coordination of effects, structures and behaviors. Intelligent model object collects, represents, carries and interprets information and knowledge about interrelated engineering decisions. Intelligent model object is prepared for remote activities of engineers and can access information, knowledge and interactions in the worldwide Internet system.

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References

[1] Nketsa Alexandre, Combettes Stéphanie, "A virtual system approach for distributed simulation of complex systems," *Proceedings of the 2002 IEEE International Conference on Systems, Man and Cybernetics*, Hammamet, Tunisia, 2002

[2] M. Tambe, W. L. Johnson, R. Jones, F. Koss, J. Laird, P. Rosenbloom, and K. Schwamb, “Intelligent agents for interactive simulation environments,” *AI Magazine,* v. 16, n. 1, 1995. [3] Mannistö, T., Peltonen, H., Martio, A. Sulonen, R., “Modeling generic product structures in STEP,” *Computer-Aided Design*, Vol. 30, No. 14, 1998, pp. 1111-1118

[3] Mannistö, T., Peltonen, H., Martio, A. Sulonen, R.: “Modeling generic product structures in STEP”, *Computer-Aided Design*, Vol. 30, No. 14, 1998, pp. 1111-1118

[4] Laszlo Horvath, Imre J. Rudas, "Evaluation of Petri Net Process Model Representation as a Tool of Virtual Manufacturing," *in Proceedings of the 1998 IEEE International Conference on Systems, Man, and Cybernetics, Information, Intelligence and Systems*, IEEE, San Diego,California, USA, 1998, Volume 1, pp. 178-183

[5] Laszlo Horvath, Imre J. Rudas, "Constraint Based Modeling of Automatic Shape Generation," *in Proceedings of the 1999 IEEE International Conference on Systems, Man, and Cybernetic, Human Communication and Cybernetics*, IEEE, Tokyo, 1999, Volume 4, pp. 457-462

[6] László Horváth, Imre J. Rudas, “Modeling of the Background of Human Activities in Engineering Modeling,” *Proceedings of the IECON' 01, 27th Annual Conference of the IEEE Industrial Electronics Society*, Denver, Colorado, USA, pp. 273-278

[7] László Horváth, Imre J. Rudas, “Emerging Intelligent Technologies in Computer Aided Engineering,” *Journal of Advanced Computational Intelligence*, Vol 4, No. 4, 2000, pp. 268-278

[8] László Horváth, “Behavior Based Modeling as a New Challenge in Application of Intelligent Computer Methods in Engineering,” *Proceedings of the 5th IEEE International Conference on Intelligent Engineering Systems 2001, INES 2001,* ISBN 952-15-0689-X, Helsinki, Finland - Stockholm, Sweden, pp. 395-400