Intelligent Assistance of Engineering Decisions

László Horváth
John von Neumann Faculty of Informatics
Budapest Tech
Polytechnical Institution
Népszínház u. 8, Budapest H-1081, Hungary
horvath.laszlo@nik.bmf.hu

Imre J. Rudas
John von Neumann Faculty of Informatics
Budapest Tech
Polytechnical Institution
Népszínház u. 8, Budapest H-1081, Hungary
rudas@bmf.hu

Abstract: The authors introduce a methodology for enhancing of engineering modeling by the description of design intent and application of environment adaptive model objects. The main objective is an intelligent modeling for the purpose of decision assistance where knowledge is integrated and embedded in or referred by the model. The proposed solution can replace the conventional modeling where knowledge is carried by generalized modeling procedures and applied directly by engineers. Paper starts with an approach for introduction of intelligence in the engineering modeling practice by the authors. Following this, some representative details of the modeling of design intent are outlined. Next, behavior driven modeling and the application of design intent and the related knowledge are explained and details are highlighted about the methodology as applied by the authors at the definition of environment adaptive integrated model objects. Finally, implementation issues are discussed.

Keywords: Product Modeling, Intelligent Engineering Modeling, Behavior Based Modeling, Modeling of Design Intent, Adaptive Modeling.

1 Introduction

Application of computers in engineering has developed into a model-based technology that includes methods for description, analysis, manufacturing planning, production planning and presentation related engineering tasks. The authors considered design intent and adaptivity related problems in contemporary engineering modeling. Two research projects have been established for modeling of design intent and development of environment adaptive model objects. They are supported by the OTKA program of the Hungarian Government. High level of integration with existing modeling of products, wide application of the well-proven application oriented feature principle, and knowledge dependence were the basic objectives. This research program by the authors represents investigations about application of human controlled and governed machine intelligence in engineering. To do this, some issues in human-computer interaction (HCI) are also critical points of this work.

Conventional modeling includes definition of input information for selected entity generation procedures, creation of entities, relating existing entities and some model based analyses. The authors were thinking about a higher level of intelligence where intent of engineers is included in the models and associative models are adaptive modified for changed circumstances, along chains of associativities. Modification is based on analysis of well-defined behaviors of the modeled objects.

The authors utilized well-proved methodologies in the proposed modeling. In recent years more flexible modeling was provided by replacing fixed model structures by object oriented, programming based reference models [1]. Behavior based modeling and application of agent technology represented the way towards intelligent modeling of engineering objects [2]. Models describe some of the modeled engineering objects by features and their attributes [3]. Relationships and associativities are defined amongst model entities and their attributes [4]. More appropriate descriptions were established for entities and their relationships [5]. The research introduced in this paper utilized some earlier results by the authors. Design intent and its integration in models are considered as the authors conceptualized them in [6]. Relationships of intent primitives define net structure as it was written by the authors in [7]. Modeling procedures use intent information to assist decisions even to make decisions automatically. This approach constitutes the basis of development of design intent driven, self and environment adaptive objects that are capable of receiving, creating and sending intent information for changes in their environment. Some preparatory research by the authors in this field was published in [8].

This paper starts with an approach for introduction of intelligence in the engineering modeling practice by the authors. Following this, some representative details of the modeling of design intent are outlined. Next, behavior driven modeling and the application of design intent and the related knowledge are explained and details are highlighted about the methodology as applied by the authors at the definition of environment adaptive integrated model objects. Finally, implementation issues are discussed.

2 A Way to Intelligent Modeling

Advanced modeling systems is being developed to provide enhanced computer assistance of engineering activities by the utilization of knowledge at creation, modification and relating of model entities. Behavior based models with intelligent content contain descriptions for specifications and knowledge in a design process oriented system. Specifications are results of design with appropriate explanations. Model of design intent is considered as described in the form of specifications and knowledge. Knowledge is normally related to given specification but it is also can be independent of any specification.

Seeking the way for enhanced intelligence of engineering modeling, the authors analyzed the utilization of knowledge by intelligent modeling as it is outlined in Fig. 1. The present modeling practice supports only representation of generally applicable and domain related knowledge. However, most of the knowledge in engineering processes is company, product, and human related. Moreover, approved knowledge changes from company to company and product to product and it must be handled with confidence. Definition of specification and knowledge needs authorization according to role of engineers in the product development team and stage of the design process.

The authors joined to the approach of integration, embedding or referring more or less knowledge in models of engineering objects is necessary. When the appropriate modeling methods will be available, the generalized knowledge in present day general purpose CAD/CAM systems will be replaced by integrated, embedded and referred knowledge. This provides a powerful assistance for engineers at development, modification, and application of models and helps to prevent quality of models from deterioration at their modifications.

Model that has the capability of reaction to changed conditions using behavior related knowledge is considered to represent a step on the way towards intelligent design of modeled objects. The main concern is communication of built in knowledge with modeling procedures and humans to save earlier decisions and human intent, and to assist definition of new decisions and intents, and capturing them in the model. In this manner, knowledge content of models is developed with development of models.

Forthcoming development and of models is concentrated on the utilization of their own intelligent content at automatic creation, modification and update of entities. Behavior based modeling offers a conversion of implicit engineering practice into explicit knowledge. Representation of knowledge should be as simple as it can be to ensure their easy definition and understanding by engineers in the every day practice. Compliance of the model with proven practices and standards also must be ensured. To achieve this, preferable forms of knowledge are formulas, rules, and checks.

A proven practice is creating models of engineering objects during design, analysis, manufacturing planning and product integration by instancing of models of abstract objects. Sometimes authors confuse abstract objects to be modeled with their models. An abstract object carries characteristics of a set of similar engineering objects. Creation of a new modeled object instance from an abstract object is the basis of creating instance model entities from abstract model entities. This process should be enhanced by increased knowledge content of models. Model of an abstract object also may involve domain, company, and engineer related knowledge. Model of an instance object generally contains domain, company, product, and engineer related knowledge. Information about origin and validation of the utilized knowledge also should be included in the model. Otherwise, responsibility for the features and behaviors of a product cannot be evaluated.

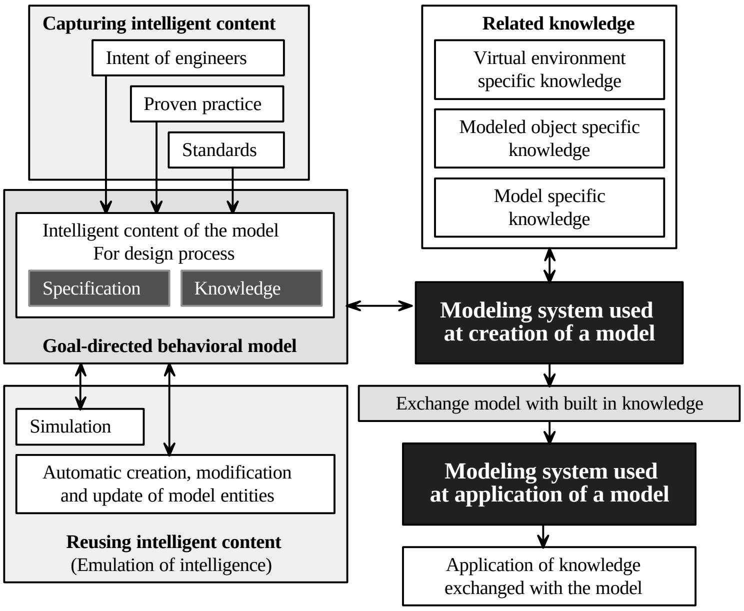

Fig. 1. Consideration of intelligent content of models for engineering purposes

3 Modeling of Design Intent

Engineering has become well-organized group work. Allowed field of solutions for a decision depends on several earlier decisions. At the same time, a decision may enforce change of earlier decisions. The authors analyzed this problem and the possibility of modeling multiple intents of engineers. Characteristics of intent description for processing in product modeling systems, as proposed by the authors, is illustrated in Fig. 2. Engineer *A* creates a model and defines intent as background information for a sequence of steps of a related decision. This typical definition starts with a goal and ends by experiments. Intent model entities are created then mapped to product model entities. After model data exchange for an application of the model, engineer *B* at the application must understand intent of engineer *A*. To achieve this, representation of intent must include information to answer all relevant questions. As an example, intent information that is attached to a geometric model entity must answer questions for preferred shape and allowed shape modifications.

Representation of design intent must be appropriate to understand by practicing engineers (Fig. 2). Engineers are familiar with simple representations as rules and checks so that these are preferred as intent entity representation. Cluster definition, taxonomy, and decision tree help engineers at classification activities, for example, at selection of proper modeling procedures or model descriptions. Decisions related to appearance of a shape can be relied upon picture or video analysis information.

Intent model entities of the proper representation are also characterized by attributes for their processing. Important attibutes and sample values some of them can be seen in Fig. 2. Application of an intent requires information about the status of the human who defined the intent. It is also an essential information for intent related decisions at application of product models involving intent information. Despite the same technical content, situation is different at different states of humans acting as source of an intent. Status of an intent carries information on its origin. Information for inherent hierarchy of origins should be included in intent models. Status is an important information for engineers for taking into account intents at decisions.

An intent according to its type may be defined as possible alternatives, compatibility, allowable ranges of parameters, fixed characteristics, results of tests, suggested environmental conditions, pros and contras, etc. Application of some types of design intent can speed up application related modeling activities at further development, modification and application of models. Suitable alternatives are described to choose from without any need for notice towards design engineer who created the product model. A parameter can be modified within an allowable range of its values without any permission.

4 Behavior Modeling Assisted Engineering

The authors proposed an extension of industrial product models by knowledge and behavior feature entities. The purpose of these new elements is to provide computer assistance for engineers during product design by communication of information about consequences of creating new or modified product model entities. The modeled world is divided into a set of engineering objects in the actual modeled world and engineering objects in the world outside of it.

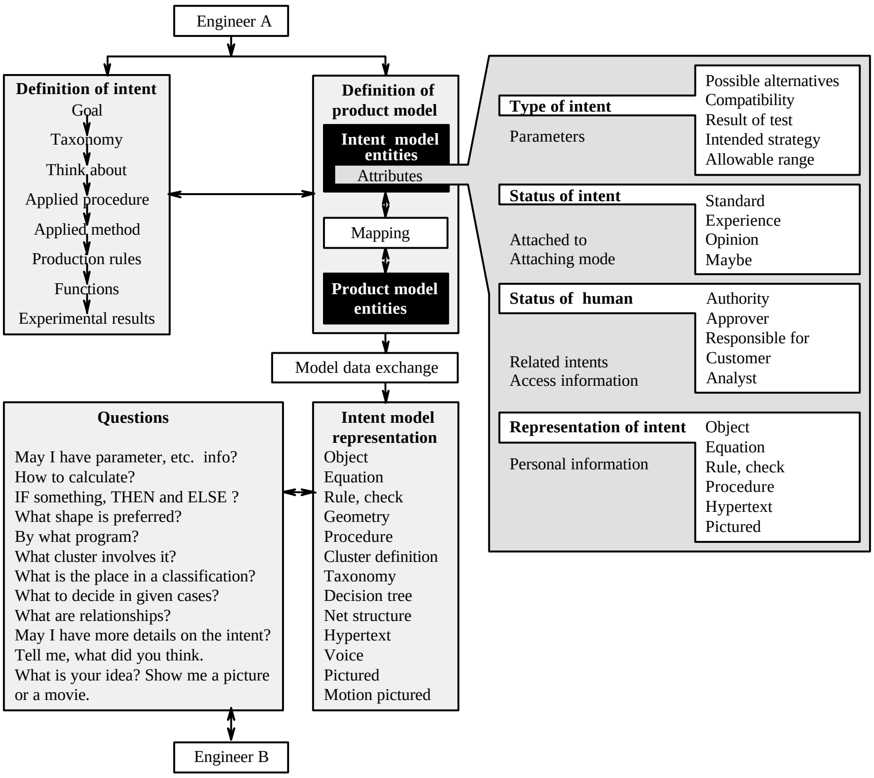

Fig. 2. Characteristics of design intent

The resulted model is more or less active one and serves as a partner of engineers at their key decisions about product related engineering objects and their parameters. It comprises knowledge from three sources, namely modeling procedure, generic part model, and engineer. Modeling of a product or its some detail is considered as a single process, from conceptualization to manufacturing even to product life end procedure, depending on the scope of product modeling process. Feature based part model as it extended by active knowledge uses comprehensive groups of features as volume adding and subtracting form features, form conditioning features, finite element features, load features, machining features, measurement features, associativity features, rule features and check features. This extension assures feature orientation throughout the entire engineering process. Design alternatives are recorded in product models together with the related knowledge.

New feature definitions are launched for the modeling system by both humans and remote created models (Fig. 3). There is an actual set of known features in the modeling system. Most of the features are generic ones and part models include their instances. Others are defined only for the model under development and can or must not be applied in other models. A generic model also can have a restricted application.

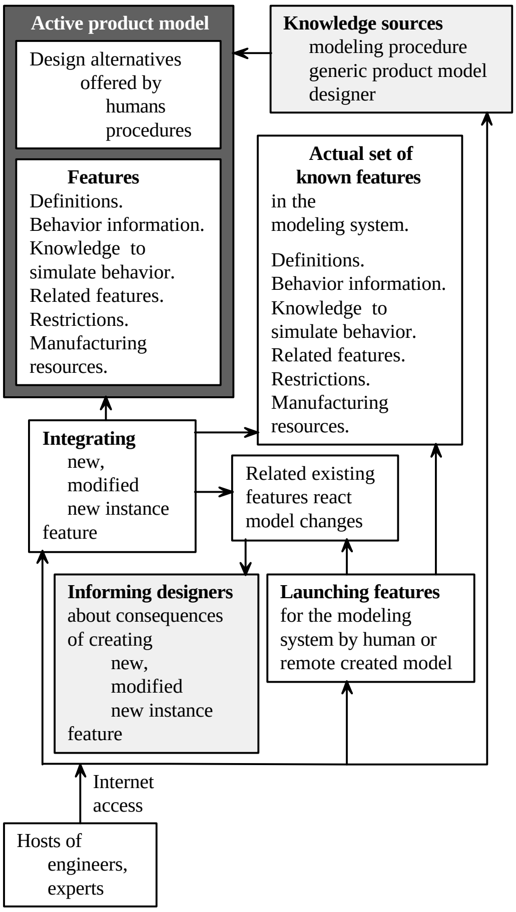

Fig. 3. Definition of features

Model describes information and knowledge necessary to simulate behavior of the modeled objects. Feature description includes environment related information as previously defined related features, restriction definitions for prospective features and production resources in order to integrate new feature in existing product model. Receiving this information, the related existing features react to the feature related model development activity. Consequently, features are aimed to create information about effects of model changes and to communicate this with the related features. The above outlined approach also offers a solution for reconstruction of exchanged models of remote situated receiving CAD/CAM systems. Engineers and experts also store definitions and behavior information for features at their hosts. This information can be accessed by remote modeling systems through Internet. Advice taking can be made available by remotely residence engineers.

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

An essential functional element of an intelligent model object is situation handling. It coordinates effects, associativities, and behaviors (Fig. 4.). Component entities and attributes are reached via structures by the help of associativity definitions. Objects in the world outside of the actual object produces input effects and receives 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.

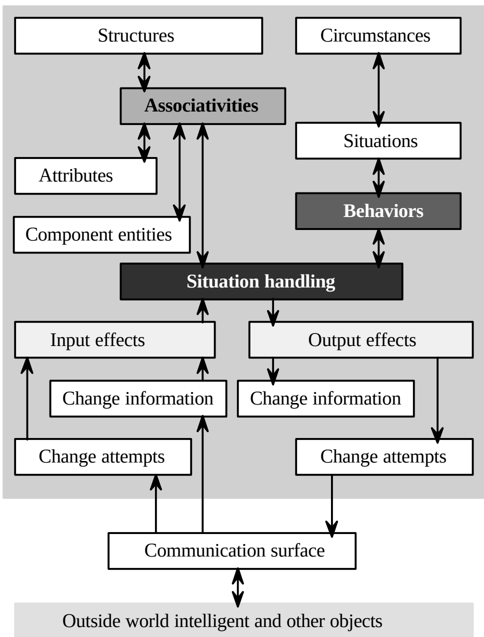

Fig. 4. Behavior driven adaptivity

5 Methodology of Environment Adaptive Integrated Model Objects

Design intent is defined in some form of knowledge except for intuitive intent. Intuitive intent is defined by circumstances. Intuition definitions can be also stored and retrieved for given circumstances. At the same time, knowledge can be connected to each circumstance. Intent is defined by active engineer who is working on the model (Fig. 5). In case of group work of engineers, a decision may be shared by two or more engineers and intent sometimes cannot be assigned to a single human. At the same time, different elements of an intent may be defined by different engineers. Active engineer uses knowledge, defines intent or retrieves own experience in the form of knowledge, uses intent of other engineers directly and considers intent of other engineers in the form of retrieved knowledge. In some cases engineer is not allowed to omit intent of some humans as chief engineers and other persons who decide on application of standards, laws, etc. Intent definitions also can be used for creation of knowledge description for appropriate knowledge sources.

Human intent based application of knowledge is inherently a restricted one. 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 by criticism. Security measures to avoid unauthorized access to knowledge are included and some knowledge can be applied but not accessed. In Fig. 5, model creation and modification are done by actions of active engineers or by adaptive actions of procedures.

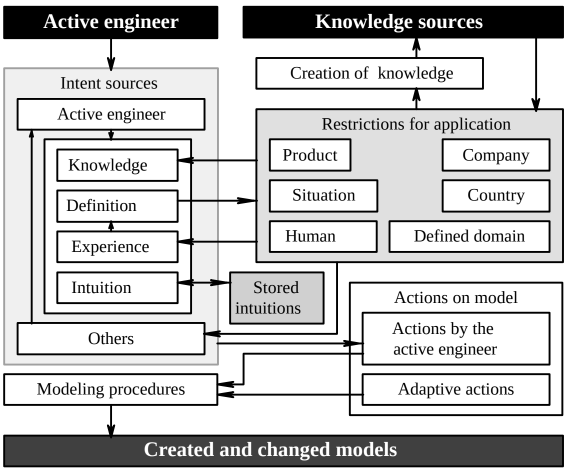

Fig. 5. Modeling by intent originated knowledge

A modeled object is characterized by several behaviors according to its technical content. Behaviors are analyzed by simulation. Simulation can be integrated in or referred from the product model object. Fig. 6 shows the arrangement when simulation is done outside of model object. Simulation takes into account actual situations. Situations are defined within the model object according to actual behavior. Model object produces actual information on the basis of information available inside and outside. Behavior information is evaluated by computer procedure or human. Procedure makes attempt to change model object as its adaptivity by its environment. Human defines new or modified intent.

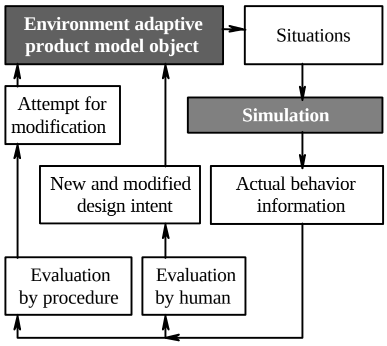

Fig. 6. Process of adaptive modeling

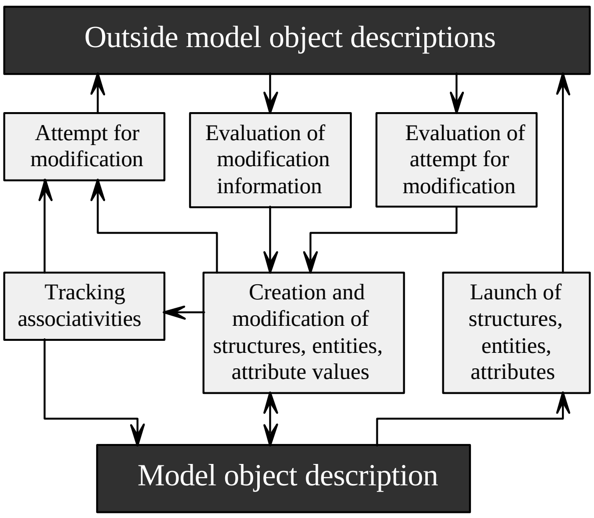

Fig. 7. Environment adaptive nature of model objects

Adaptive functions and their connections are presented for a model object in Fig. 7. Most of the 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. 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. When an associativity is defined as a constraint, the propagation is compulsory.

6 Some Implementation Issues

Structure of an intent description is determined by relationships of intent primitives. Fig. 8 illustrates an intent that consists of four intent primitives. Relationships are defined for pairs of intent primitives to arrange them in a structure. Processing of this structure produces a decision of the engineer who is responsible for it. That engineer is also responsible for definition and application of the constraints defined by the relationships between intent primitives.

Intent primitives are often act as alternatives because of a decision of an engineer. Selection of the best solution, taking into account alternatives, is not always supported by an additional relationship for hierarchy of alternatives. In these cases, the problem cannot be handled by simple consideration of relationship definitions. Effect of the related intent primitives on design should be also evaluated. Rules and checks help engineers in doing this. Simple structure of intent primitives in Fig. 8 is typical for simple decisions. However, solving complex problems is the most important area of effective application of intent modeling. Intent model must be completed with an information that carries impact information for intent primitives. Impact of an intent primitive sometimes is simply the consequence of its source.

In the present style of engineering work, engineers are invited to work in groups, depending on actual tasks and human expertise. Huge amount of useful intent model primitives and structures can be stored in the relevant computer systems and can be retrieved when they are appropriate for an actual engineering task. When design of a new product starts, earlier defined design intent descriptions can be utilized to assure a continuity of product design at the company as well as in the domain. For this purpose, stored situation dependent intent descriptions are applied. Engineers can establish self-assistance by definition and storage of intents including circumstances for later tasks with similar circumstances.

Intent may be not effective because of a stronger intent under the prevailing circumstances. However, changes in circumstances during later development or application of the modeled engineering objects can give more chance for that intent. Related intents have to be included in the model in order to save the chance for successful reconstruction of the original thinking process that can lead to a recognition of beneficial application of intents abandoned earlier.

List of intent primitive definitions in Fig 8 is not intended to be a complete one; it only illustrates composition of an intent description. The intent modeling is aimed as fully integrated with product modeling. Most of product modeling related information is associated with design, analysis, and planning of computer controlled manufacturing of mechanical parts.

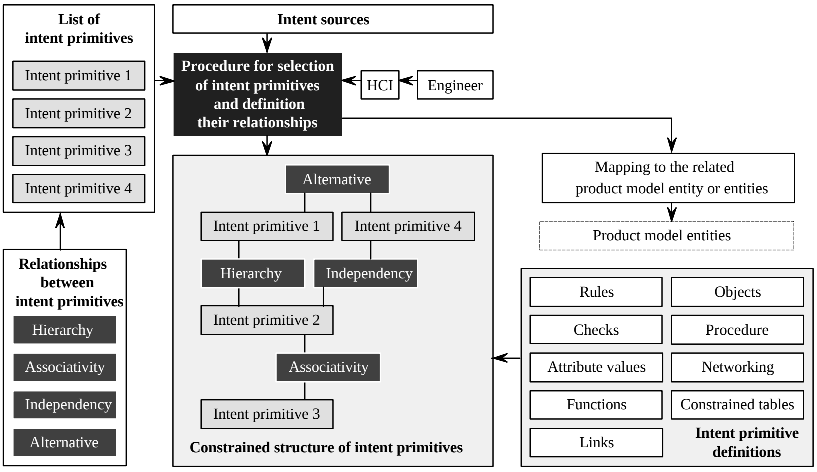

Fig. 8. Composition of intent description

One of the most difficult tasks in engineering is related to conflicts of design intents. Several essential capacity and intent breaking issues are listed in Fig. 9. Capacity issues restrict resources as engineers, model entity types, parameter ranges and values, solutions, methods and facilities. Restrictions control application of resources. Results of analyses and experiences suggest restricted or preferred solutions. Purpose of threshold knowledge is saving basic intents and quality of decisions. Intent breaking issues mean stored or communicated intents contradicting other intents. New or modified decisions may be enforced. Strategies, decisions, and solutions are stored and applied at later decisions. Resolution of conflicts caused by intent breaking is considered as computer representation of argues amongst engineers. Resolution by hierarchy of intent holders should be avoided but it is normal in every day engineering practice. Capability driven change of intents is forced by real world circumstances. On the other hand, consideration of some new resources may produce solutions acceptable by all holders of conflicting intents.

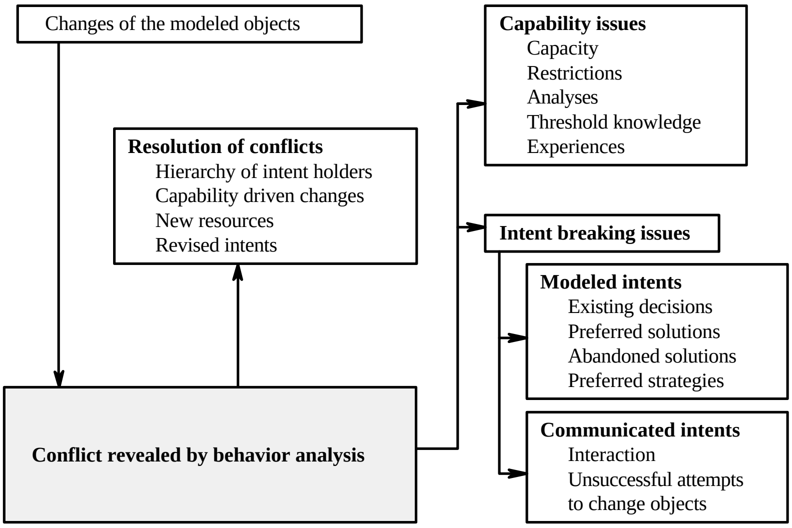

Fig. 9. Handling of conflicts

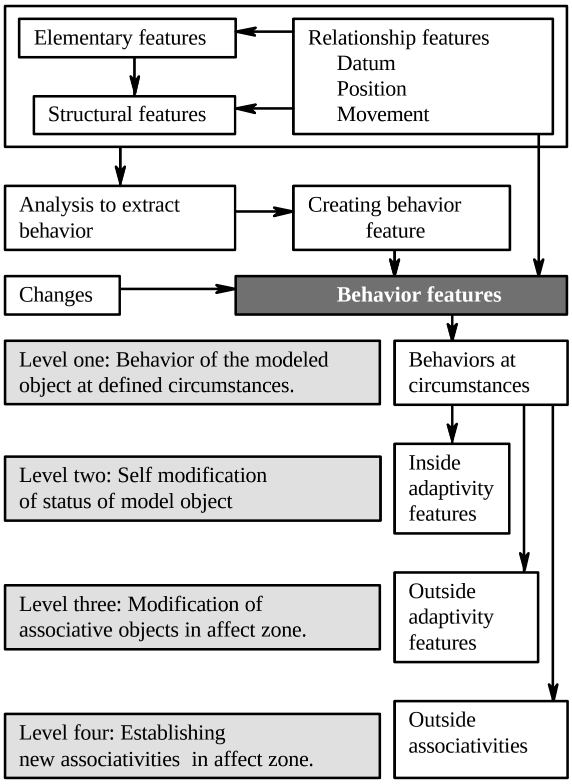

Fig. 10. Behavior feature driven activities on four levels of the model

Active object activities are modeled in a multilevel schema. Figure 10 explains behavior feature driven modeling activities on four levels. Behavior features are extract and created during behavior analyses. Elementary, structural and relationship features, existing in the actual product model, are also utilized at creation and modification of behavior features. This process is not discussed in this paper.

On level one, actual behaviors of the modeled engineering objects are defined for given situations. On level two inside adaptivity features are applied for modification of model object entities as a consequence of the communicated changes. On level three outside adaptivity features are applied for making attempts to modify model entities outside of the model object. Sometimes behavior features propose modifications of non-associative entities. In these cases, new associativity definitions are initiated. Following this, a repeated attempt is necessary to modify the new associative objects, as an activity on level three. Unaccepted associativities are undergone to conflict handling process.

It also can be concluded from the above discussions, privacy policy is an important aspect at implementation of the proposed modeling. Results of engineering activities are resultants of different, sometimes contradicting human intents.

Conclusions

Human centered aspects of modeling is proposed and discussed in this paper as a development of engineering modeling toward intelligent systems. The objective of the related research by the authors is development of highly integrated, adaptive model objects. Intelligence of these objects relies upon knowledge modeled on the basis of organized human intent descriptions. Frequent modifications of model objects are handled by extensive adaptivity for control of content of the model objects and their environment. Adaptivity has been made working by chains of associativities. This method makes it possible to integrate the modeling in conventional modeling systems to enhance their intelligence. Application orientation of models is assured both by knowledge and feature definitions. Decisions are supported by situation-based analysis of behaviors.

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