Intelligence for Assistance of Engineering Decisions in Modeling Systems

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Abstract: Activities of engineers for design, analysis, manufacturing planning and other purposes constitute a complex structure of decisions. Recently, integrated modeling systems support product lifecycle data management. Model entities are organized in structures by associativity definitions between entities. The authors introduce several methods to include intelligence into these systems. Key method is extension of the feature principle to allow definition of comprehensive sets of application oriented entities by engineers. The paper starts with an outline of the approach by the authors to modeling by behavior and adaptivity features as an extended application of the feature principle. Following this, a description of engineering objects is proposed to accept intelligence for decision support. Next application of behavior driven adaptivities is explained. Finally, handling and processing of human intent filtered corporate knowledge is detailed.

Keywords: Product modeling, support of decision making, behavior based modeling, human intent modeling.

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1. Introduction

In recent years, a great change in engineering work has moved activities of engineers into comprehensive software systems. Multiple engineers work in these global or less extended environments. Multiple human intents are to be considered in decisions. A decision depends on several other decisions mainly by engineers who are not available at later changes required by development, variant creation, custom and other demand generated modification of product data. The authors considers any modification of model of interconnected modeled objects as attempt for modification that must be accepted by humans responsible for engineering activities regarding associative modeled object that must be changed if the attempted change is approved. The authors propose an intelligent method to solve this problem.

The authors did works in projects connected closely with the reported research. They analyzed modeling in CAD/CAM systems [1], application of behavior definitions and adaptive functions to assist decisions and propagate their effect [2], modeling of human intent as background of decisions [3], and integration of human intent modeling in modeling of mechanical units [4]. They proposed a modeling for handling of changes in models of engineering objects by propagation of effect of changed entities [5].

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 [6]. 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 [7]. 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 [8]. Description of form features [9] and surfaces in boundary representation represents an outstanding development of shape modeling in the last decade.

In this paper, the authors introduce several methods to include intelligence into these systems. Key method is extension of the feature principle to allow definition of comprehensive sets of application oriented entities by engineers. The paper starts with an outline of the approach by the authors to modeling by behavior and adaptivity features as an extended application of the feature principle. Following this, a description of engineering objects is proposed to accept intelligence for decision support. Next application of behavior driven adaptivities is explained. Finally, handling and processing of human intent filtered corporate knowledge is detailed.

2. Modeling by Extended Application of Features

Approach by the authors to engineering object definition is summarized in Fig. 1. Engineering objects are described by features. Component objects are described as elementary and knowledge features. Structural and relationship objects are described by structure and relationship features, respectively. An elementary feature can be placed in one or more structures. The above listed elements of models represent advanced engineering modeling. The authors have completed this palette by behavior and adaptivity features for the description of active objects. Important capability of recent engineering models is description of product variants. Elementary, structural and relationship features are capable to describe variants.

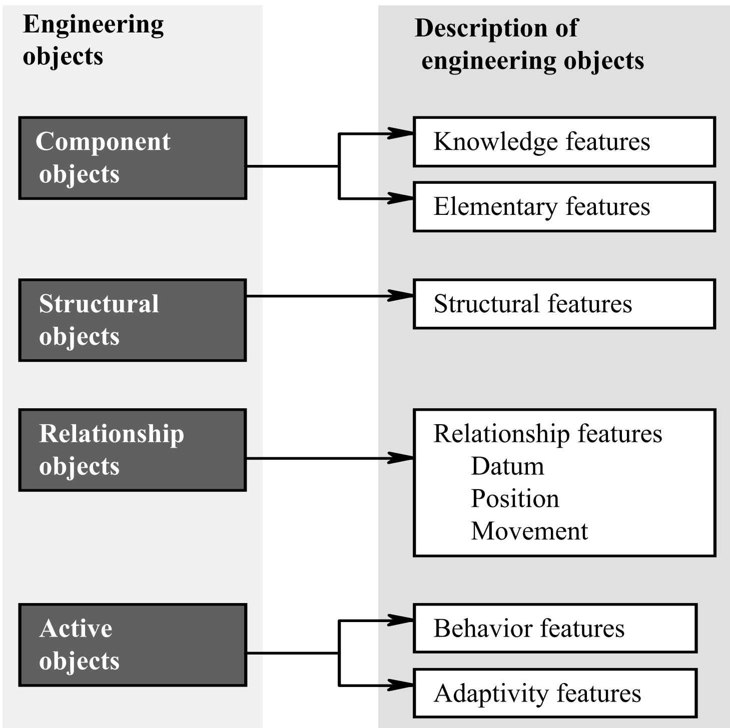

Figure 1: Object definitions

Behavior features are created then applied according to a four-leveled model of behavior and associativity related activities of an arbitrary composed integrated model object (Fig. 2). Elementary, structural and associativity features, in generic or instance product models, are applied at creation and modification of generic and product related behavior features. On level one, actual behaviors of the modeled engineering objects are defined for given circumstances. On level two, inside adaptivity features are created and applied for modification of model object entities as a consequence of communicated changes. On level three, outside adaptivity features are created and applied for making attempts to modify model entities outside of the model object. Behavior features may reveal a need for modifications of non-associative engineering objects, inside or outside. In this case, new associativities are to be defined on the level four. Following this, repeated attempt to modify the newly associative objects, as an activity on level three is necessary.

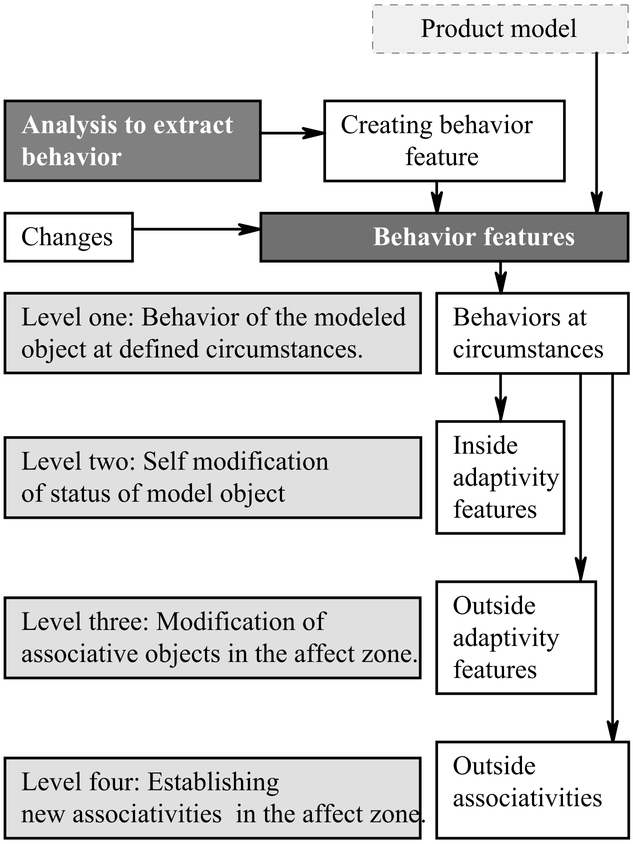

Figure 2: Four leveled model to handle behaviors and adaptivities

3. Description of Engineering Objects

Behavior driven functionality of an integrated model object allows for receiving input effects and creating output effects. Effects are generated and processed by behavior-based analysis (Fig. 3). Behaviors of the modeled object are elaborated by using of circumstances. Circumstances are defined by using of elementary functions, responses, and actions. Circumstances and situations organize behavior-based knowledge. As a consequence of the behavior-based analysis, key functional element of an adaptive model object is situation handling. It coordinates effects, structures, and behaviors, identifies circumstances, sets situations, and produces reactive behaviors. Component entities and their attributes are accessed through structure descriptions, by the help of associativity definitions. Objects in the world outside of an actual integrated model object produce input effects and receive output effects through a communication surface. Structure and component entities and their attributes are changed according to decision by situation handling.

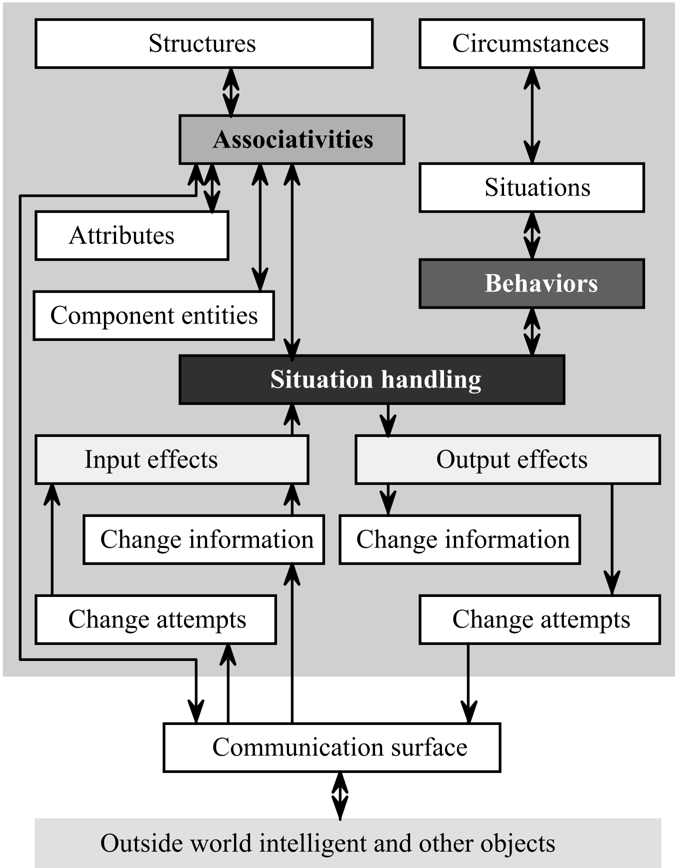

Figure 3: Handling of changes bay situation based behavior analysis

Integrated model object comprises associative entities. It constitutes a unit organized and configured for processing, inside, and outside communication. Integrated model object works in connection with conventional modeling where modeling, group work and product data management tools are available for handling model entities, collaboration of engineers as well as process and multimodeling based management of product data. In the structure of an integrated model object (Fig. 4), the passport gives general status, acceptance, permissions and other access and application related information. Other important structural elements of an integrated model object are definitions, instances, and communications. Procedures are organized by managing function. Inside and outside communications are handled along associativities. Sets of new associativities are generated according to newly emerged demands for communication. As an auxiliary function, communication also can be done by conventional data exchange with systems without associative connection. Fig. 4 also outlines main categories of definitions. Engineering objects are described by entities. A solution comprises a set of entities representing interrelated engineering objects for a well-defined engineering purpose. Behaviors are defined according to the goals associated with the modeled engineering objects. Behaviors are analyzed for situations. A situation is composed by a set of circumstances.

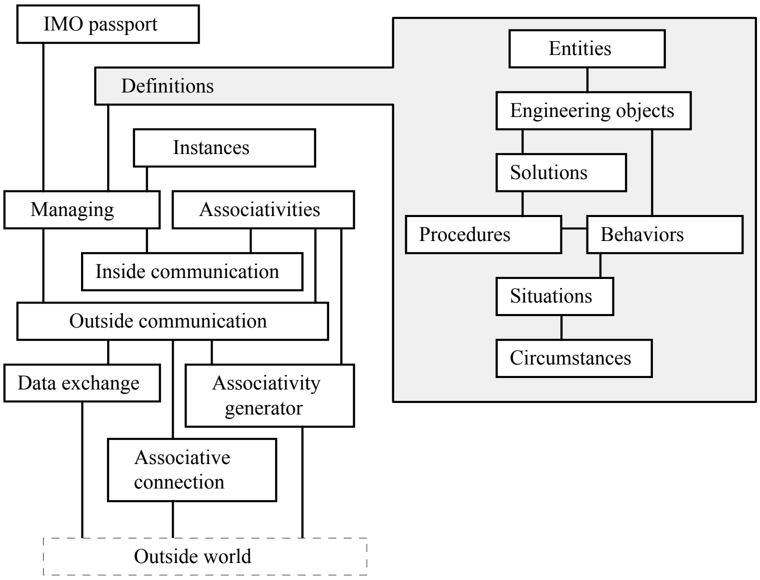

Figure 4: Structure of an integrated model object (IMO)

4. Behavior Driven Adaptivities

Recent achievements in commercial product modeling can be summarized as a mixed application of its feature based, parametric, associative and adaptive characteristics (Fig. 5). Present models consist of elementary features, their instances, structure features, and associativities. For example, a part is an elementary feature. Its instances are placed in an assembly. Structure feature is the assembly tree and associativities are applied at placing the part in the assembly.

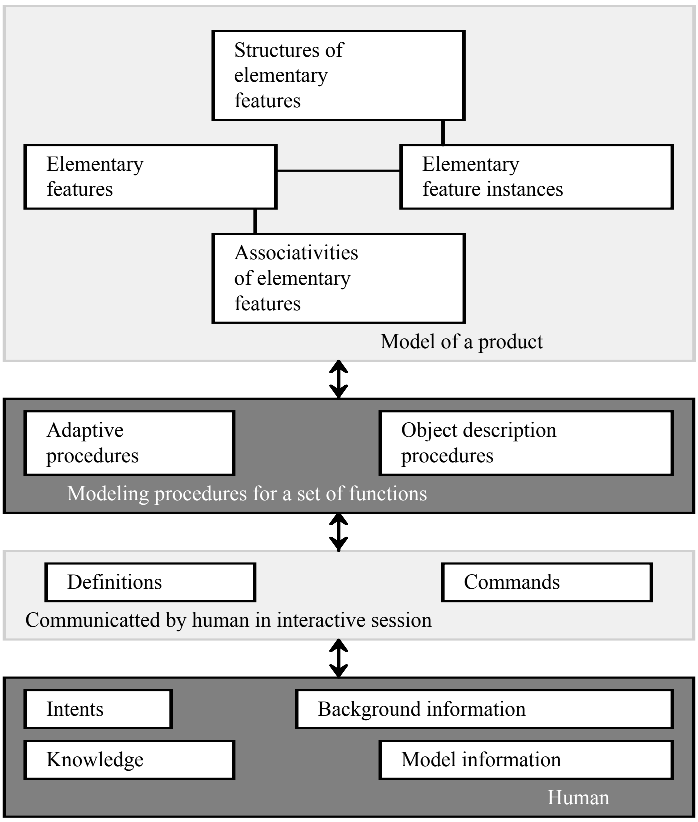

Figure 5: Modeling in recent CAD/CAM systems

As other example, a part feature is a structure of shape modifications, elementary feature is a form feature, its instances are placed in arrays, and associativities are applied between elements of a contour. Adaptive modeling has the capability of modification of entities and their parameters by using of initial rough results. For example, a finite element mesh is generated as a rough one. Then adaptive meshing refines it. Object description and adaptive procedures are placed in modeling systems outside of the model. Exchanged model information is handled by modeling procedures other than the original ones by which they were created. It is impossible to make modeling system that has the capability of understanding all exchanged models correctly. Human gives definitions and commands in an interactive way to control the modeling process. Correctness, appropriateness, and consistency of the model are established and controlled directly by the quality of human activities. In this engineering process, human cannot concentrate on essential decisions because the so many details to be handled.

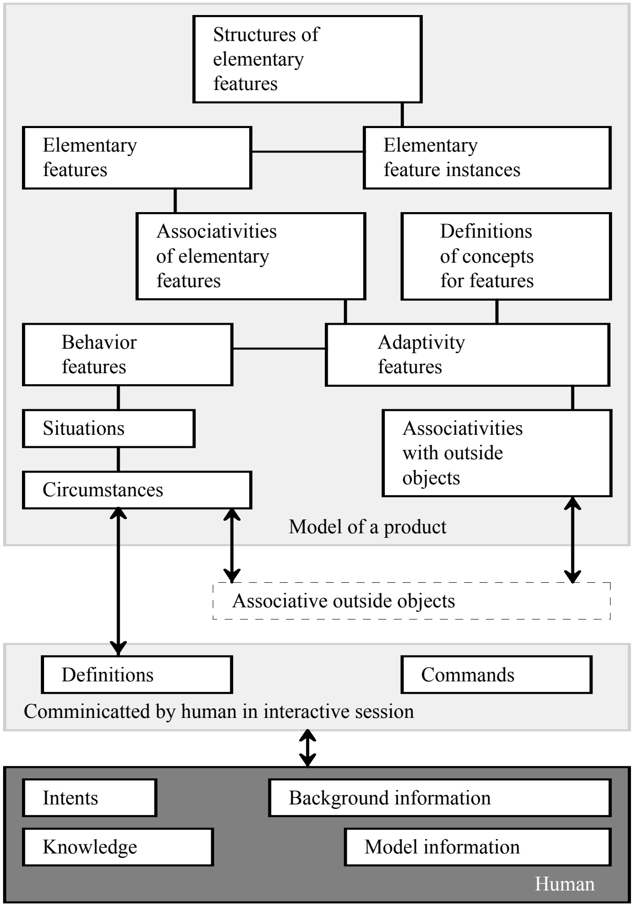

Figure 6: The proposed product modeling

The proposed product modeling is relied on description of behaviors and adaptivities (Fig. 6). An integrated model object consists of three modules. They are inside modeled object information, behaviors and adaptivities. The engineering strategy for characteristics of the product is distributed amongst behaviors. A behavior represents an independent design objective. Behaviors may need coordination. Any information from the engineers and outside of the domain of modeling is considered as circumstance. Circumstances are applied at creation of situations. Situations are processed by behaviors. At the same time, behaviors generate information for adaptivities for the modification of the model or associative outside objects. Adaptivities also supply model object information for the behaviors. The method of modeling is wide application of the feature principle.

5. Human Intent Filtered Knowledge

The authors analyzed design intent based, highly integrated and environment adaptive modeling of products as a next step in the development of intelligent models. They consider creation and modification attempts on models as communication of human intents. Human intents are added to a model object from the creation of the first entity to end of its life. Intent sources are engineers who work on the actual project, all other engineers involved in concepts, methods, knowledge and information applied at modeling, experts included in the project, and other outside effects as standards and legislation. Intent is considered and handled as knowledge.

Knowledge is embedded in model, integrated with it or related to it (Fig. 7). The related knowledge may be imported with translation before its application. Modeling is defined on three levels that ensures implementation of the proposed modeling as an upgrade of an existing modeling. The authors applied well-proved modeling methodologies. On the application level, model includes entities for description of some modeled objects by features and their attributes. On the level of relationships, associativities are defined amongst model entities and their attributes. This can be a simple rule to calculate some attribute values or even a complete taxonomy. On the level representations, best appropriate description is established for entities and their relationships. Modeling of design intent can be applied for development a system that describes and processes all information about a category, type or series of a product. Intent bank provides information about previous and related decisions and it can be used at decisions similar to some previous ones. Lists can be extracted, for example, for actual problems to be solved, unsolved problems during earlier product design and similar decision processes from successful engineers.

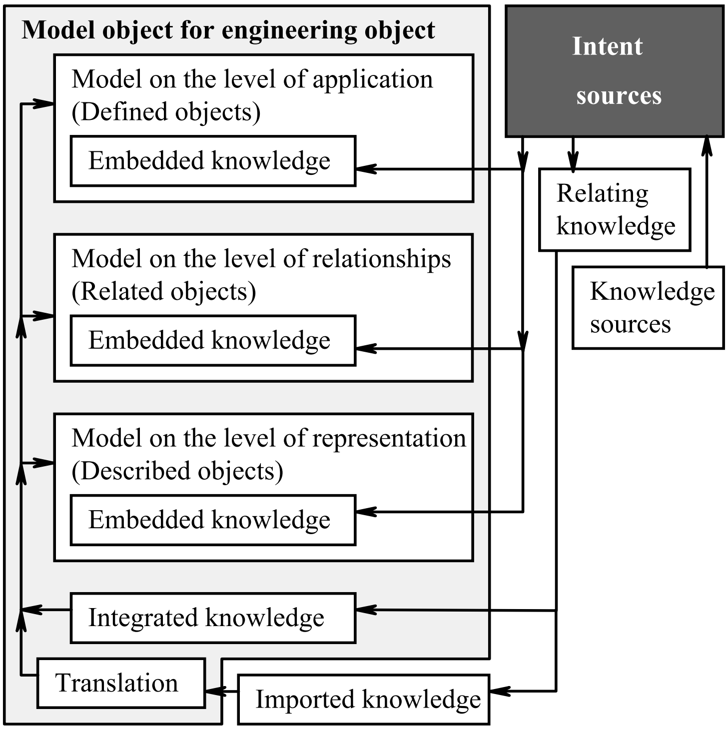

Figure 7: Including knowledge in a three leveled model

Most of intents are defined by an active engineer who is working on the model (Fig. 8). In case of group work of engineers, a decision may be shared by two or more engineers so that intent can not be assigned to a single human. In this case, different elements of intent are defined by different engineers. Active engineer uses knowledge, defines intent or retrieves own experience in the form of knowledge, uses intent of other engineers and considers intent of other engineers in the form of retrieved knowledge. In some cases, engineer is not allowed to omit intent of chief engineers and other persons who decide on application of standards, laws, etc. Intent definitions also can be used at creation of knowledge description for appropriate knowledge sources. In Fig. 8 model creation and modification are done by actions of active engineers or by adaptive actions of procedures. Human intent based application of knowledge is inherently restricted. 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 with criticism. Security measures to avoid unauthorized access to knowledge are included.

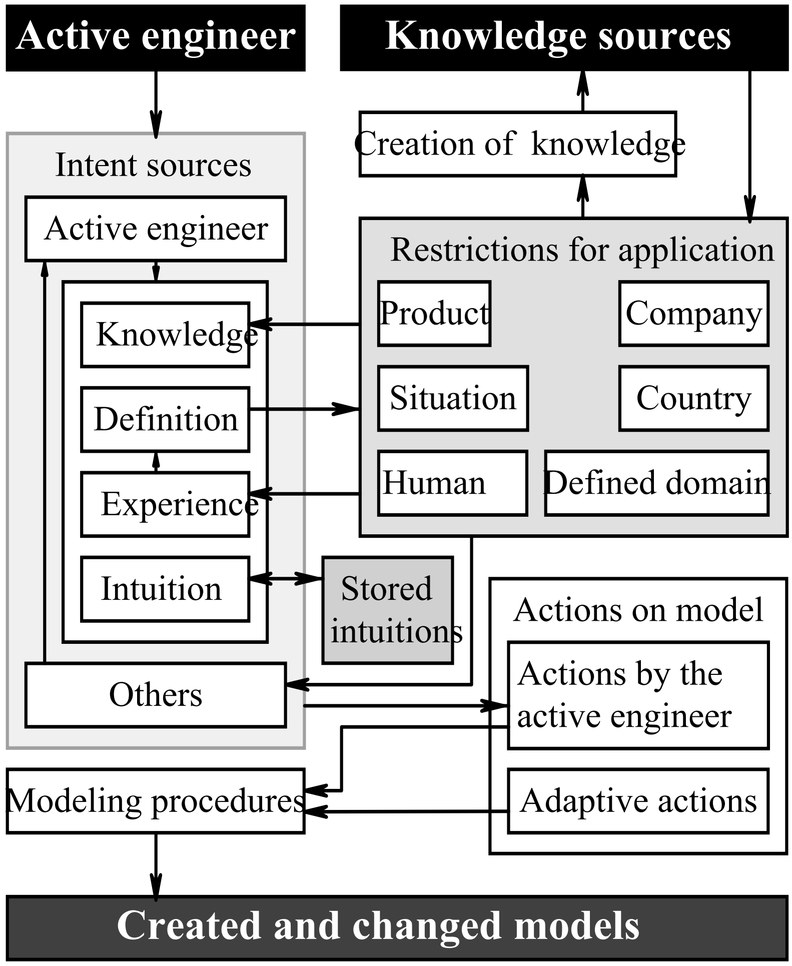

Figure 8: Intent filtered knowledge

Knowledge features are application oriented descriptions of strategies, solutions, experiences, etc. At the same time, model includes decisions and design intent [5]. One of the issues for coordination of behaviors is resolution of conflicts (Fig. 9). Conflict may be originated from capability related problem or breaking some human intent. Conflicts need coordination of behaviors. Capacity as the maximum available resource may restrict resources such as engineers, model entity types, parameter ranges and values, solutions, methods, and facilities. Restriction controls application of resources. Results of analyses and experiences also may suggest restricted or preferred solutions. Engineers, who are responsible for their decisions have responsibility-based privileges. Results of decisions are represented by appropriate product model information. Other intent related information comes directly from the user dialogue. Conflicted intents occur in every day engineering practice. Other sources of conflict of intents are outside world objects, which may not accept attempts for their modification by adaptivity module of an integrated model object. Intent breaking may come from stored or communicated intents that contradict actual intents enforcing new or modified decisions. Purpose of threshold knowledge is saving essential intents and quality of decisions. Strategies, decisions, and solutions are stored for later decisions.

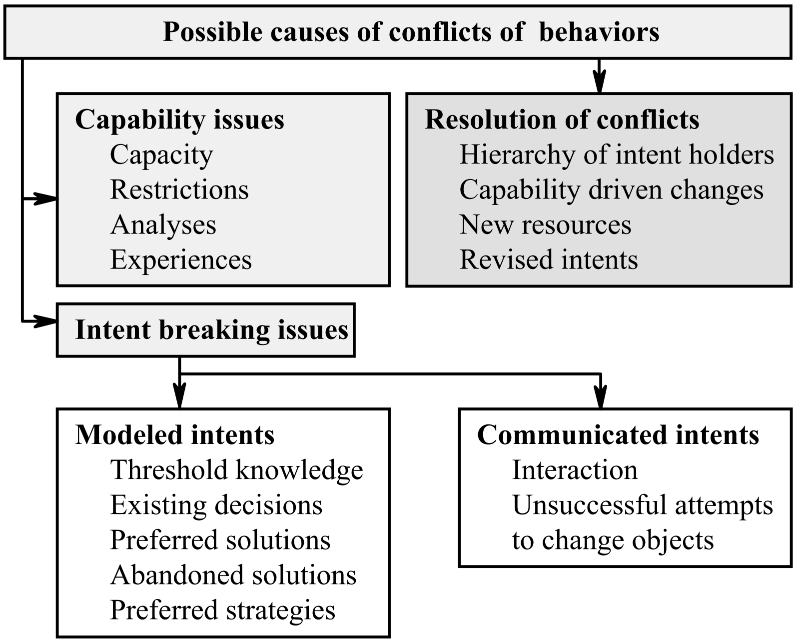

Figure 9: Conflicts

6. Conclusions

As a contribution to capture intelligence in every day modeling activities by engineers, integrated model objects are analyzed and methods are proposed for adaptive modeling. Intelligent model objects are aimed to be suitable as intelligent computer representations in complex engineering systems. Effects of changes in the actual model object and in other model objects related to it are analyzed. 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. Conflict may be originated from capability related problem or breaking some human intent. Conflicts require coordination of behaviors.

Acknowledgments

The authors gratefully acknowledge the grant provided by the OTKA Fund for Research of the Hungarian Government. Project number is T 037304.

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