Some Possibilities for Integrated Intelligent Object based Engineering Modeling

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 propose a product modeling where active model entities are organized in purposefully configured, highly integrated model objects featured by arbitrary and developing complexity and mutual adaptivity with their environment. Behaviors initiate adaptive actions as reaction for changes inside and outside of a model object. Object in this concept is associative with all related objects, changes and develops itself and its environment and has human intent originated content. Elementary, structural, relationship, behavior, knowledge, and adaptivity features compose model objects. Potential application area of the modeling is mechatronics where wide variety of mechanical, electrical, electronic and software engineering objects are to be related. The proposed modeling can be implemented within the framework of recent industrial CAD/CAM systems. In this paper, an introduction of the proposed integrated objects for engineering modeling discusses structure and communication related issues. Following this, behavior based adaptivity of the model object and connections of product model behavior features are explained. Next, application of behavior based adaptivity for the control of changes is detailed. Then, modeling of human intent based knowledge for intelligent engineering is discussed and the proposed intent model is detailed. Finally, future research and implementation issues are concluded.

Keywords: Product modeling, behavior based modeling, modeling by features, knowledge based engineering, large-scale integration of models

1 Introduction

Computer description of highly related engineering objects constitutes conventional models. STEP standardized product model to describe all required engineering objects in a well-organized stucture using special language EXPRESS [1]. The authors propose a product model that consists of model objects featured by arbitrary and developing complexity and mutual adaptivity with their environment. Object in this concept is associative with all related objects, changes and develops itself and its environment and has human intent originated content.

The authors applied well-proved modeling methodologies. In recent years behavior based modeling and application of agent technology represented the way towards intelligent modeling of engineering objects [2]. On the application level, models include entities for the description of some modeled objects by features and their attributes [3]. On the level of relationships, associativities are defined amongst model entities and their attributes [4]. This can be a simple rule to calculate some attribute values or even a complete taxonomy. On the representation level the best appropriate description is established for entities and their relationships. The authors did some earlier works in intelligent engineering modeling. Design intent and its integration in the model are considered as the authors conceptualized them in [5]. The authors applied the method of decomposition at analysis of decisions. A decision is defined as a sequence of steps with individual intent definition. Modeling procedures use intent information to assist decision or even to make decision 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 is published in [7].

In this paper, an introduction of the proposed integrated objects for engineering modeling discusses structure and communication related issues. Following this, behavior based adaptivity of the model object and connections of product model behavior features are explained. Next, application of behavior based adaptivity for the control of changes is detailed. Then modeling of human intent based knowledge for intelligent engineering is discussed and the proposed intent model is detailed. Finally, future research and implementation issues are concluded.

2 Integrated objects for engineering modeling

Integrated model object comprises associative entities. It constitutes a unit organized and configured for processing and 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. 1), 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. 1 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.

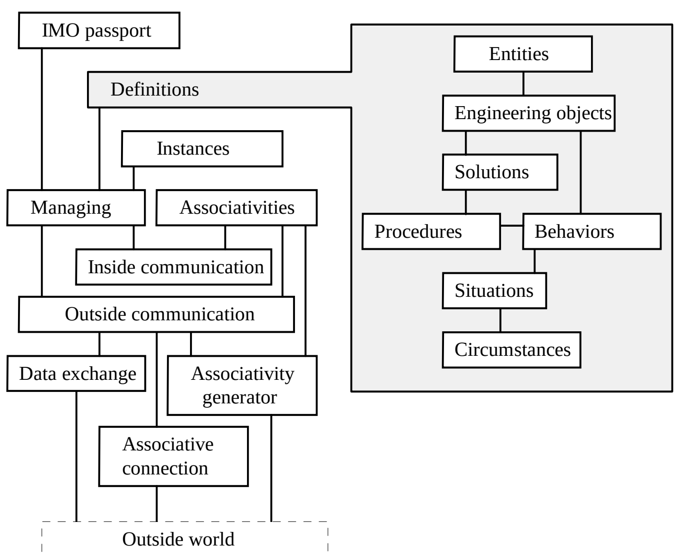

Fig. 1 Structure of an integrated model object

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. 2). 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.

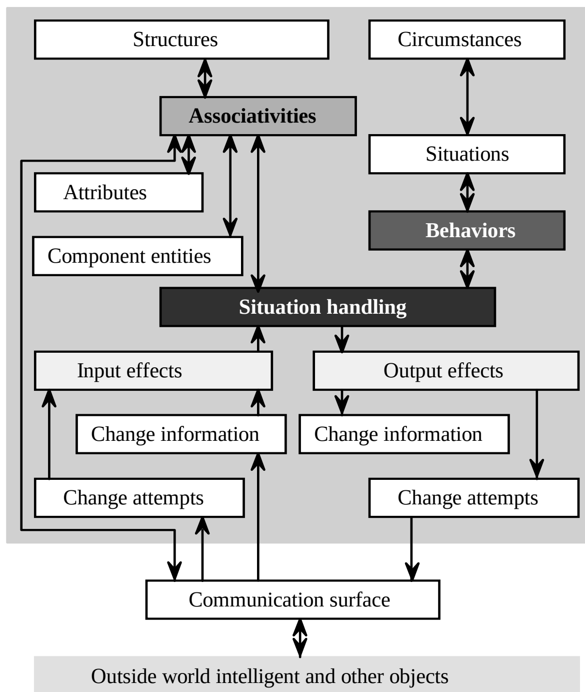

Fig. 2 Communication of an integrated model object

Elementary, structural and associativity features in generic or instance product models are applied at creation and modification of generic or product model instance related behavior features. Extending the feature sets of advanced industrial modeling systems, behaviors and associativities are defined as features, in connection with features for the description of modeled objects. Behavior features are defined by analyses then applied on level one of a four leveled model of behavior and associativity related activities within an integrated model object (Fig. 3). 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. Behavior features often reveal needs for modification of non-associative engineering objects, both inside and outside. In this case, new associativities are defined on level four. Following this, repeated attempt to modify the newly associative objects, as an activity on level three is initialized.

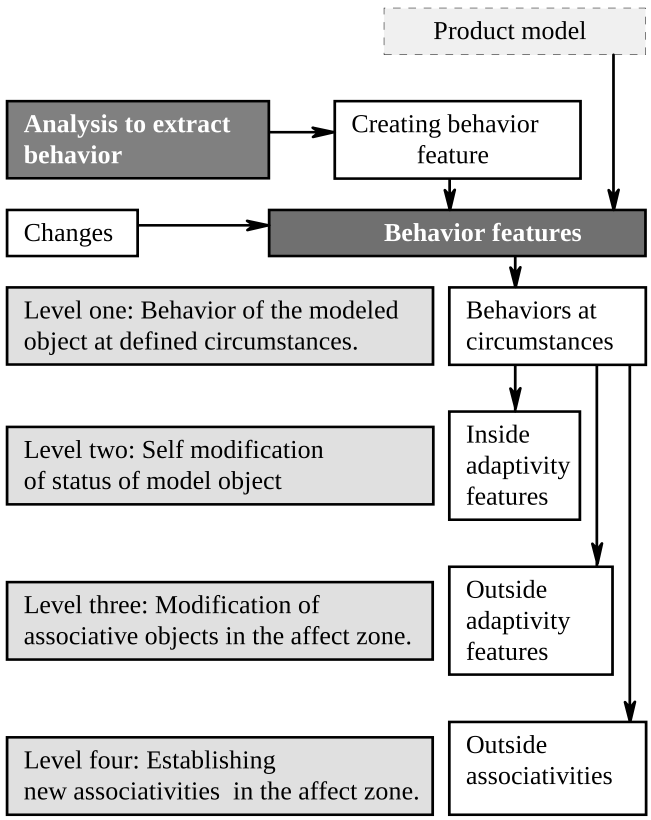

Fig. 3 Four leveled modeling by behavior and associativity features

3 Behavior based adaptivity for the control of changes

Role of managers in an environment adaptive model object is shown in Fig. 4. Basic components of engineering model object as entities, their structures, attributes, and relationships carry results of decisions. Intent manager handles intents of engineers and other humans. Any change of a model object is initiated by new or changed design intent.

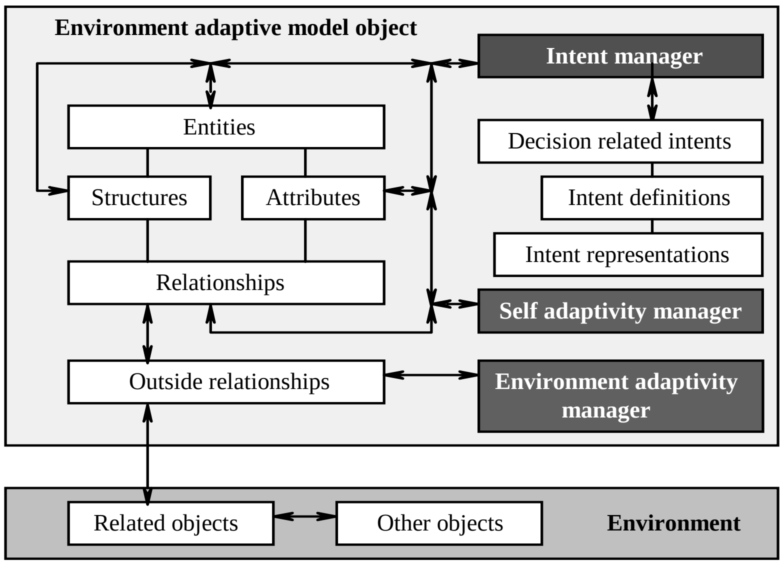

Fig. 4 Managers in an integrated model object

In the logical structure of product model by the authors, behavior features are attached to product model features (Fig. 5). Associativities can be defined along connections arbitrarily. This modeling is engineering process-oriented. Both humans and active models control the modeling process. Behaviors are originated from customer demands, requirements by engineering activities, experiences, and personal intents. Fig 5 shows several examples for behaviors in a mechanical system, as there are cooperating with features typical in present industrial modeling systems.

Engineering objects are physical as components of products and production equipment or logical as a process. A set of related behavior definitions are attached to each engineering object. Mechanical parts, for example, have behaviors such as shape, dimensions, connections, effects generated by loads, standards, visual attraction, manufacturing, and function. Shape behavior is analyzed by situation comprising circumstances about type, attributes, and representation. In case of example on Fig. 6, circumstances are characterized for a swept surface. Type of surface needs sweeping by using of generator, path, and spine information in the form of curve entities. At the same time, scale and continuity conditions are specified as circumstances. Attributes of the shape are dimensions, tolerances, and surface roughness. Representation of the surface is parametric B-spline, defined by range of parameters, as well as knot and weight vectors.

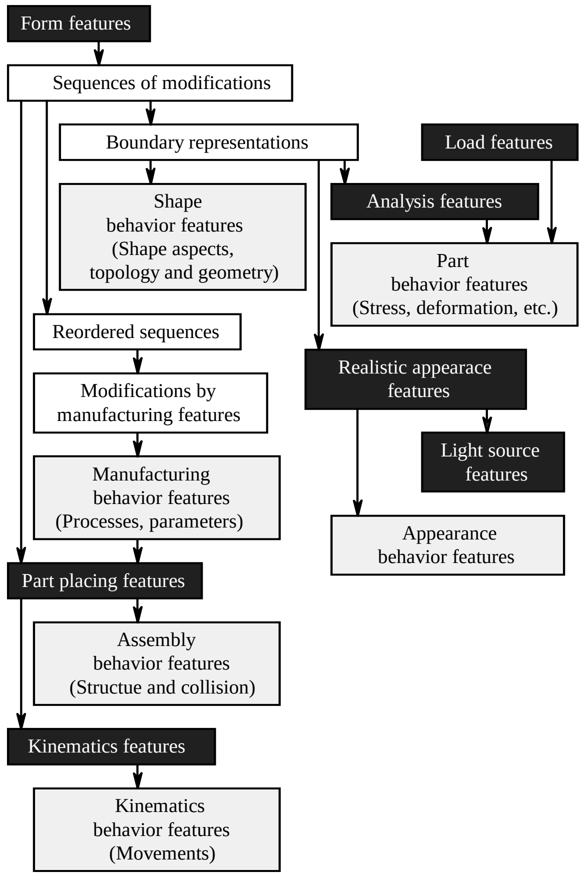

Fig. 5. Features and behaviors in model of a mechanism

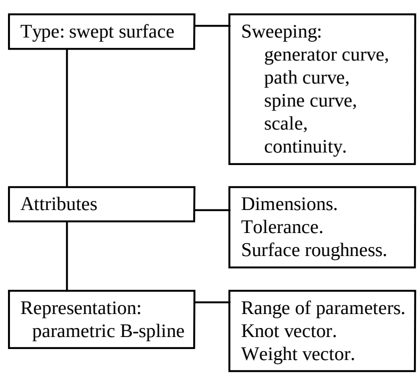

Figure 6. Circumstances for a shape behavior feature

4 Human Intent based knowledge for intelligent engineering

A well-organized engineering process relies upon clearly defined responsibilities. Engineers make decisions according to their roles and responsibilities and utilize expertise of other engineers. The engineer who is responsible for an actual decision is the active engineer (Fig. 7). Intent is considered as the background of a decision and the authors discussed it in [5].

Active engineer uses knowledge, defines intent or retrieves own experience in the form of knowledge, and considers intent of other engineers in the form of considered or retrieved knowledge. In some cases, engineer is not allowed to omit intent of chief engineers or other persons who decided application of standards, laws, etc. Intent definitions also can be used at creation of knowledge description for appropriate knowledge sources. Model creation and modification are done by actions of active engineers or by adaptive actions of procedures (Fig. 7). 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 emphasizes one of the most important characteristics of knowledge: It is not generally applicable and it is accepted with criticism. Security measures to avoid unauthorized access to knowledge are included.

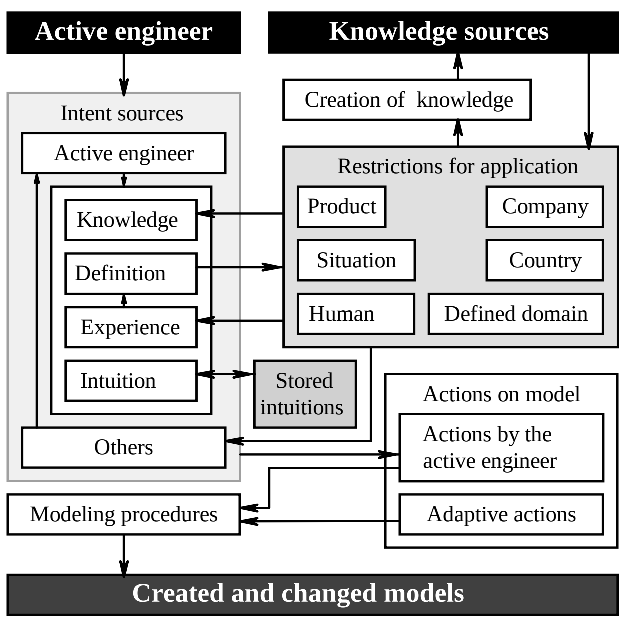

Fig. 7. Knowledge as design intent

Intent is described by intent primitives, as well as their attributes and interrelations (Fig. 8). Actual sets of intents are defined according to the domain, field and task of applications. Intent is attached to a decision on an entity, a parameter or a relationship of parameters in a model of engineering objects. An intent description is basically a history and appears as a sequence of steps to a decision in the form of intent primitives. However, intent primitives are also connected logically by relationships between pairs of them.

The history can be considered as a chain of explanations for a decision. Fig. 8 shows an example for one of the possible styles of history. A goal is defined and a related taxonomy is revealed. This is followed by a consideration on the procedure to be applied as result of thinking process of an engineer. Then the applied method is selected, taking into consideration the choice that is offered by the selected procedure. Alternative procedures and methods can be involved or referred. The procedure needs input data that has been defined using production rules, functions and experimental results. The origin of experimental results is an important element of the intent description.

Processing of an intent description produces a decision by the engineer who is responsible for it. Engineer is represented by intent primitives and constraints defined by the relationships between pairs of intent primitives. This method, proposed by the authors, guarantees the quality of the model. Engineers often define intent primitives as alternatives. The selection of a solution, taking into account alternatives, is not always assisted by relationship for hierarchy of alternatives. If not, the problem cannot be handled by processing of relationships and effect of the related intent primitives should be evaluated. Intent model must be completed by information that carries a measure of impact of intent primitives. Impact of an intent primitive sometimes is simply the consequence of its source. Solving complex problems is the area of effective application of intent modeling.

Attributes apply for a single intent or a group of intents. Three essential attributes are type of intent, status of intent, and status of decision-maker. Representative values of these attributes are exampled in Fig. 8. Intents are application oriented ones so that actual sets of possible attribute values are defined according to needs of the application and its domain. Application of an intent requires information about the status of the human who defined the intent. 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 about its origin. Information for inherent hierarchy of origins should be included in intent models.

Intent information is attached to a decision regarding characteristics, elements, structure, and attributes of the modeled object. Intent is active when it can control even initiate procedures (Fig 9). It should be defined previously. Passive or descriptive intent is a record of the background of a decision as in conventional modeling. In this case, engineer defines intent on the basis of a recent decision. An example for passive intent description is explanation in an expert system.

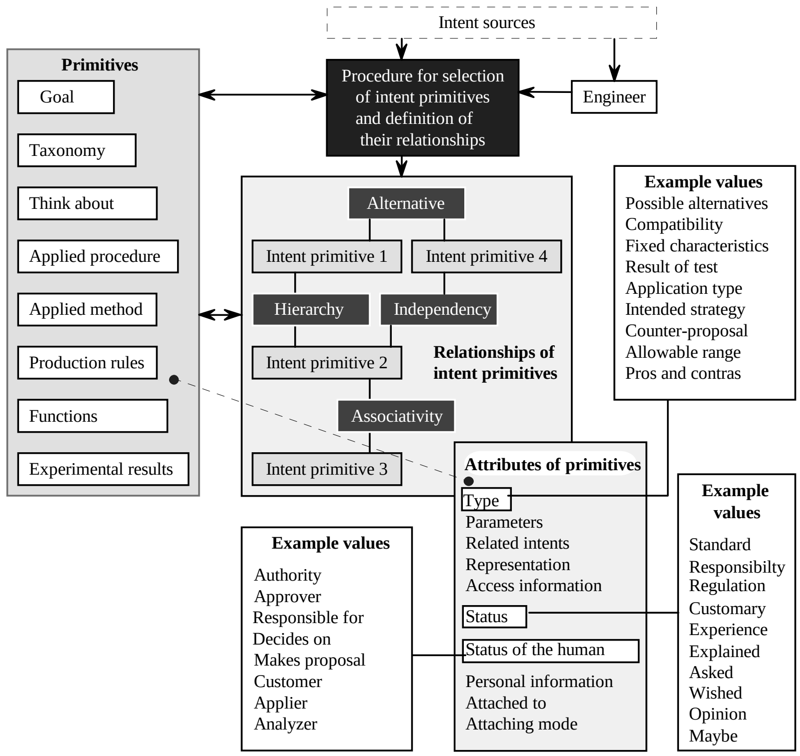

Fig. 8. Model for description of design intent

Knowledge features are application-oriented descriptions of strategies, solutions, experiences, etc. At the same time, model includes decisions and design intent [6]. Recent modeling systems create information for several versions in a single model. Intent definition can be applied to describe conditions for versions of a product. In Fig. 9, 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*.

One of the issues for coordination of behaviors is resolution of conflicts (Fig. 10). Conflict may be originated from capability related problem or as attempt for breaking a human intent by other intent. Capacity as the maximum available resource restricts resources such as engineers, model entity types, parameter ranges and values, solutions, methods and facilities. Restrictions control application of resources. Results of analyses and experiences also may suggest restricted or preferred solutions. Engineers who are responsible for their decisions generally have responsibility-based privileges. Results of decisions are represented by appropriate product model information. Main sources of conflict in integrated model objects are intents from inside and outside world objects that may not accept attempts for their modification by adaptivity features. Intent breaking may come from stored or communicated intents that contradict actual intent 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.

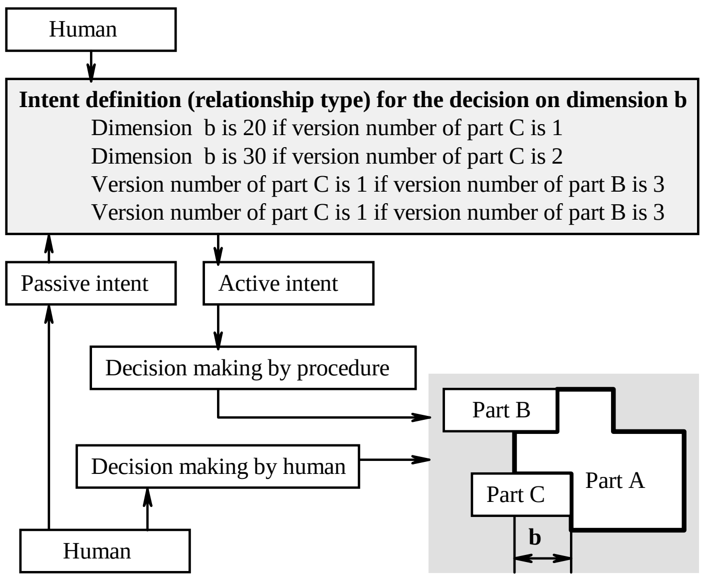

Fig. 9 Passive and active intents

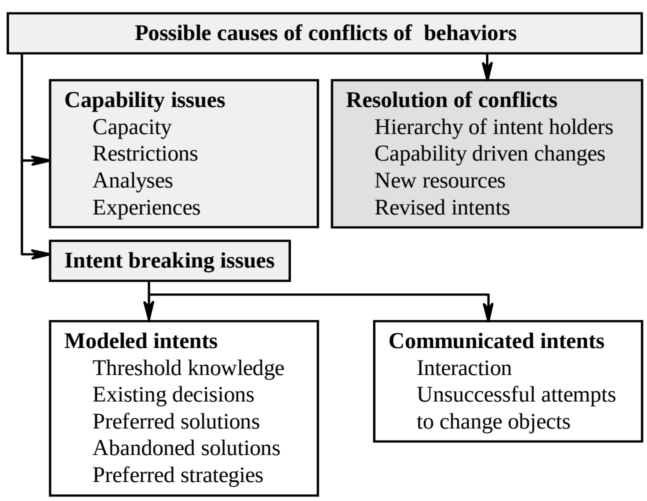

Fig. 10 Behavior related conflicts

5 Future research and implementation

To this point, research has revealed essential mechanism and relationships of the proposed integrated model objects. The human intent based development of descriptive, adaptivity and behavior features constitutes a strong methodological background of modeling. Next stage of the research is intended to do in three directions. One is a deep study and analysis of evolution of model objects. The other is definition of features in real world engineering environments. The third is cooperation of model object with well-established models in the present and foreseeable future industrial engineering practice.

The main issues of implementation of the proposed modeling are knowledge and intelligent computing methods, software technology for integration of objects in industrial engineering modeling software as an extension and development of efficient human computer interaction procedures to give the chance for engineers to efficient control of the adaptive procedures.

Conclusions

The authors proposed highly integrated, self and environment adaptive model objects for description of strongly related engineering objects. Intelligent model object collects, represents, carries and interprets information and knowledge about interrelated engineering decisions. Engineer defines knowledge as design intent, applies knowledge at the definition of design intent, and defines intent on the basis of experience and intuition. Environment adaptive model objects are featured by design intent controlled self and environment adaptivity. Behaviors are identified by using of circumstances and situations. Effects, structures, and behaviors are coordinated in the proposed method. The proposed modeling is best appropriate for engineering design tasks where the design is under frequent changes, or complicated network of relationships makes tracing of effects of changes difficult. The authors think that the proposed modeling is a contribution to future application of intelligent computing in engineering design.

Acknowledgments

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

References

[1] 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

[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] Jami J. Shah, Martti Mantyla, Jamie J. Shah: “Parametric and Feature-Based Cad/Cam: Concepts, Techniques, and Applications”, John Wiley & Sons;1995

[4] László Horváth, Imre J. Rudas: “Virtual Technology Based Associative Integration of Modeling of Mechanical Parts”, *Journal of Advanced Computational Intelligence, Intelligence*, Vol 5, No. 5 2001, pp. 269-278.

[5] László Horváth, Imre J. Rudas, Carlos Couto: „Integration of Human Intent Model Descriptions in Product Models”, *In book Digital Enterprise - New Challenges Life-Cycle Approach in Management and Production*, Kluwer Academic Publishers, pp: 1-12.

[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: “Intelligent Computer Methods in Behavior Based Engineering Modeling”, *Bridging the Digital Divide: Cyber-development, Human Progress, Peace and Prosperity, Proceedings of the 2002 IEEE International Conference on Systems, Man and Cybernetics*, ISBN, Hammamet, Tunisia, pp: WP1F2.