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Intelligent Modeling Method for Development of Shape Centered Products in Collaborative Engineering

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Abstract: Modeling of engineering objects such as product elements and structures, analyses and tests, production environments, production processes, customer services has been developed to a level where sophisticated descriptions and modeling procedures serve lifecycle management of product information. The problem is that effects of a change of an engineering object are still hard to follow and evaluate in large product model systems. The authors consider inappropriate organization of product information management as the main cause of this situation. They proposed a new design objective and human intent based method for change management at engineering for shape-centered products. In this paper, brief characterization of recent professional product modeling and several related researches introduce discussion about the problem. Next, a new approach to product development in virtual emphasizes key issues in the proposed modeling. Following this, a method is proposed for product change management. Finally, virtual space as an advanced environment for product development by using of the proposed method is conceptualized.

Keywords: product modeling, virtual space, change management, behavior-based modeling

1 Introduction

By now, advanced information and computer science and technology thoroughly changed activities of engineers. Paper and electronic drawings have been replaced by description of products including manufacturing and customer related objects and processes. Robust methodologies are available in highly integrated engineering systems called as product lifecycle management (PLM) systems. Recently, these systems are being moved into Internet portals. In this form, they serve as integrators of work of engineers in projects. Extended companies can be established in well-organized computer systems. The main essence of this new style of engineering is integrated description of engineering objects in computer models. While processing of these models is highly automated, human interface processes are relatively poor. The main problem is the low-level support of decision making on an engineering object by a human considering other related decisions, human intents, knowledge, and legislation. The authors make research in this problem area for twelve years. Considering their earlier and recent results, they would like propose a method as a contribution to a higher level of decision assistance in PLM systems.

In this paper, brief characterization of recent professional product modeling and several related researches introduce discussion about the problem. Next, a new approach to product development in virtual emphasizes key issues in the proposed modeling. Following this, a method is proposed for product change management. Finally, virtual space as an advanced environment for product development by using of the proposed method is conceptualized.

2 Background

As the background of the reported research, state-of-the-art in professional engineering modeling, recent advances in research for description of engineering objects, and advancements in intelligent computing were considered. A systematic outline and understanding of recent techniques in engineering modeling by the authors was published in [12].

One of the main advancement in product related engineering was change to form feature driven modeling of parts during the nineties. Shape centered modeling where any other product information can be mapped to shape information is suitable for most of the products in industry. The methodology as proposed in this paper is intended only for shape-centered modeling. The authors considered proven modeling techniques. As an example, a method is given for multipurpose application oriented recognition of features in [1]. Emphasis is placed on the feature principle by the authors in efforts to extend the feature principle behind the well-proven form features.

Other important area of model development is integrated product modeling for concurrent engineering. Concurrent integrated engineering by integration of typical product related engineering activities is introduced in [2]. Reference models, resources and application protocols are essential elements of integrated product modeling [3]. Behavior description [4] in models represents an initial stage of intelligent engineering modeling. Advancements in widespread application of computer systems for engineering purposes is stimulated by advancements in the area of digital computer principles [5].

In [6] Petri net representation is proposed for design and implementation of an execution control, which, through suitable graph-search algorithms, generates sequences of task activation/deactivation operations, which execute the desired commands maintaining the system in admissible configurations. Machine learning is essential in case of unforeseen environmental conditions. Environment composed by known and unknown elements are typical at certain applications.

Robot controller can learn on-line about its own capabilities and limitations when interacting with its environment. A method is proposed in [7] where off-line supervised neurofuzzy learning and on-line unsupervised reinforcement learning, and unsupervised/supervised hybrid learning are applied at control of gripper. Application of fuzzy methods is of essential importance [8], among others at reduction of rule sets at representation of corporate knowledge. Authors of [9] demonstrate that knowledge level based explanations of cognitive processes provided by traditional artificial intelligence and approach of embodied systems interacting with the real world in new AI can be unified. Author of [10] examined how UML, as the most widespread modeling tool of object-oriented software development, supports practical user interface development. He proposed application of the usage interaction model and the usage control model, each of which can be described by supplementing well-known UML diagrams. Modeling often serves special applications such as geometric modeling in reconstructing surgery [11].

References of research results by the authors below represent preliminaries of the reported research. The authors analyzed modeling in CAD/CAM systems, especially application of features, adaptive processes and associativities [13]. Other relevant activities by the authors were studying application of behavior definitions and adaptive functions to assist and propagate decisions [14], modeling of human intent as background of engineering decisions [15], and integration of human intent descriptions in engineering models [16]. They proposed a modeling that is appropriate for handling of changes in models of engineering object by definition of new entities for propagation of effect of changed entities [17].

3 A New Approach to Product Development in Virtual

Virtual environment consists of a rearranged industrial modeling and extensions for descriptions and processing (Figure 1). Associative entity definitions connect objects inside and outside of a virtual environment. Knowledge includes engineer-friendly descriptions for rules, checks, reactions, situations, and connectivity as neural network. In Figure 1, several most relevant recent procedures are emphasized because they do not considered as parts of the conventional engineering modeling. They serve handling user-defined subsets of product information called as views, collaborative access and connection, adaptive actions for situations evaluated by behavior analysis, and engineering specific browsing.

In Figure 2, changes of product information are sensed from outside world. For this purpose, associative object definitions connect different groups of engineering objects. Changes of certain circumstances in the outside world are recorded as senses. Associative connection definitions are retrieved from the product model in order to mapping of sensed information to affected engineering objects. A new situation about affected objects is evaluated by using of behaviors of appropriate engineering objectives. Actual corporate knowledge assists behavior analysis by support of evaluation of actual behaviors. Finally, result of behavior analysis is utilized at creation of change actions.

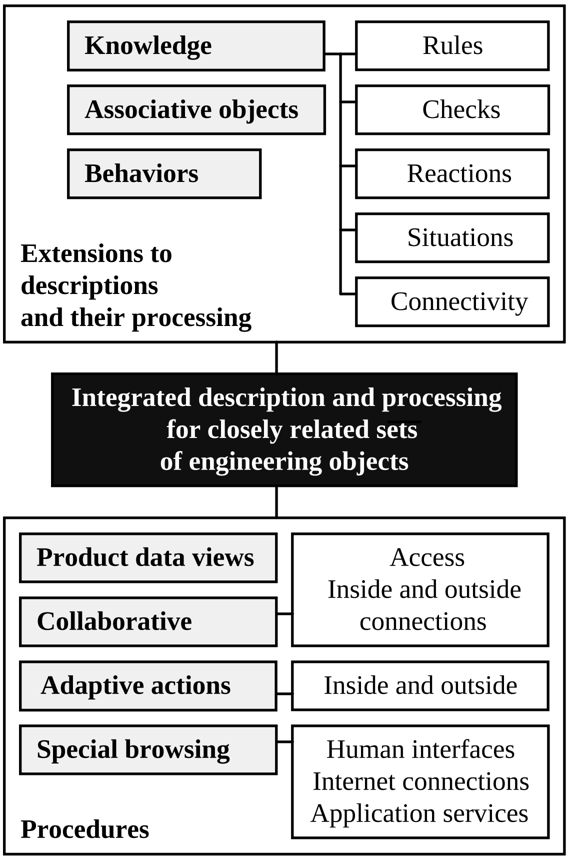

Figure 1
Outline of the proposed approach

In accordance with essential connections (Figure 2), essential procedures are outlined in Figure 3. Engineering processes apply description of products using typical groups of modeling procedures. Information exchange processes import information from and produce similar information for the outside world. Outside world is defined as all the related engineering objects placed outside of an arbitrarily grouped set of model descriptions. Associative definition manager connects input information to the product model. At the same time, associative definition builder establishes new connections for behavior analysis backed action definition. Action definition initiates creation of new or modified model entities.

Humans control behavior analysis and model creation procedures through human–computer interaction (HCI) procedures. All actions are coordinated and executed by action manager including actions concerning the outside world.

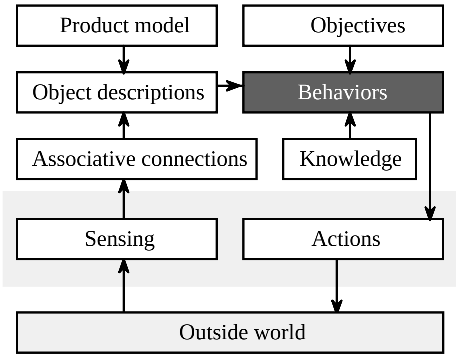

Figure 2
Essential connections

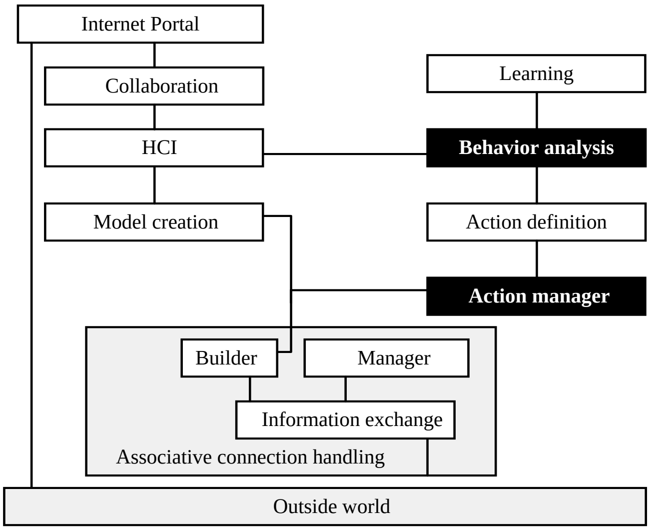

Figure 3
Essential procedures

4 Product Change Management for Design Objectives

Management of modeled object changes requires a possibility for tracking along change chains in order to evaluation all possible consequence. Development, variant creation and correction actions by engineers involved in the engineering process as well as other engineers are considered as changes. Evaluation analyzes the appropriateness of a new proposed attribute value of a modeled engineering object for design objectives of the related product. Built-in intelligence lets engineer to know attributes of modeled objects that produces the specified behaviors and that how a modeled object with a given set of attribute values will behave. A modeled object is characterized by behaviors according to relevant specification. It is assumed that any change of an engineering object may affect one or more behaviors. Consequently, any changes of an engineering object and other engineering objects associative with it in its affect zone may require new evaluation of behaviors. Affect zone of an engineering object defines a set of engineering objects that may require modifications as a consequence of its change. In order to ease of processing, behavior is defined for situations. Because behavior represents a design objective, its specification may be also changed.

Attributes, behaviors, associative connections, knowledge, and adaptive actions are defined for modeled objects. These rely on definitions of engineering objects, data descriptions, behaviors, solutions, situations, circumstances, and procedures. Model representation for the defined, related and mapped knowledge can be selected using rich methodology of computational intelligence.

Behavior specifications are composed considering customer demands, requirements by engineering activities, experiences, and personal intents. Behavior features describe behaviors of the related modeled object at different circumstances. Active behaviors define parameters of the modeled objects while passive behaviors serve for comparison of specified and actual behaviors. As an example from shape centered product modeling, four behaviors are defined for a swept surface in Figure 4. Behaviors serve design objectives for shape, placing of surface in a part and its structural environment, continuity specification, and parameter controlled local characteristics of the surface.

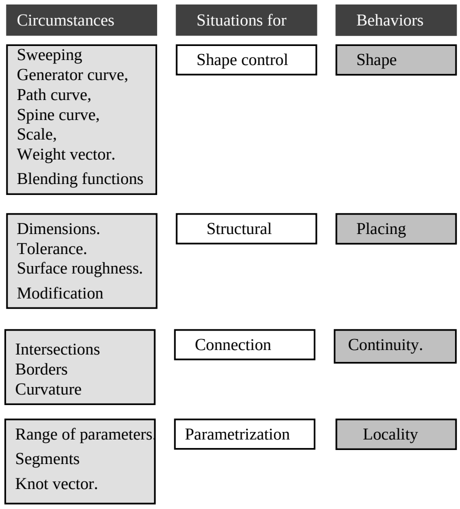

Figure 4
Example of surface behaviors

The change management (Figure 5) receives information about accepted and proposed changes from interfaced humans and outside world. Changes are mapped as conditional adaptive actions. The next step is an analysis of their effects on associative modeled objects. The consequences of changes are often calculated directly, as modifications of elementary or composition object descriptions. Sometimes simple changes are abandoned due to improper changes of behaviors. Alternatively, behaviors can be changed. Effect analysis for a change often generates additional changes even initiates now chain of changes. Messages about these changes are analyzed as new change information. Accepted decisions are considered as final adaptive actions. Inside changes are executed while outside changes are proposed. In the outside world, change attempts are accepted or rejected, and new changes are generated.

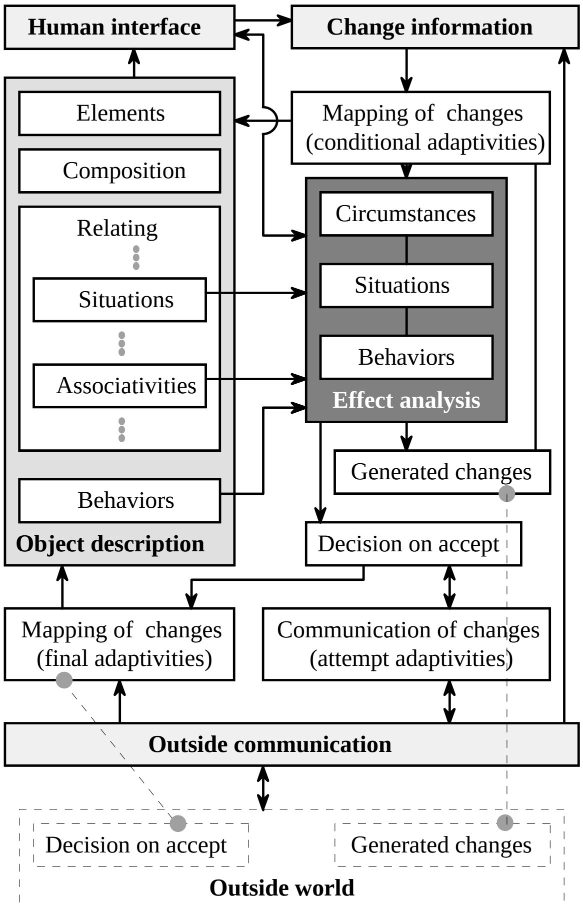

Figure 5
Management of changes of modeled objects

Change management by the authors is also aimed at integration of different analyses in a product modeling. It visualizes consequences of a change and allowed directions of new and new changes and acts as an advanced navigator. When a change request is rejected due to improper changes of specified behaviors, resolution of conflict of different human intents is necessary. In an environment like this, engineers have much more chance to find a conflict free solution than in conventional product modeling.

One of the main problems emerged at computer model supported decisions is that consequence of a change of a model describing several interrelated modeled objects extends to outside of a modeling environment. The above problem enforces integration of different modeling systems into a system of systems in extended enterprises. This circumstance encouraged the authors to study outside connections of a modeling environment. Despite efforts to models standardized by reference models and application protocols, incompatible models even not modeled objects are to be interfaced.

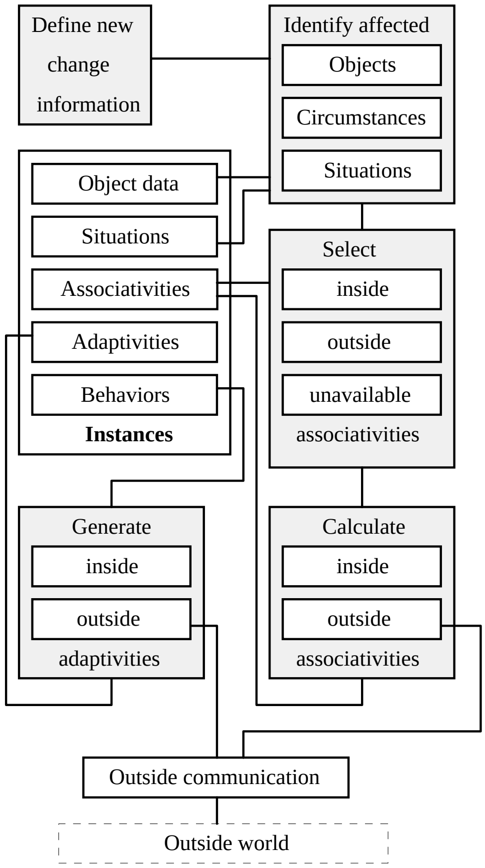

Figure 6
Processing change information

Main steps of change information processing are explained in Figure 6. Inside, outside and unavailable associative connections are selected. Unknown associative connections cannot be considered by the intelligent processing. They are considered by the human who controls the actual engineering process. Following this, inside and outside associative connections are calculated and adaptive actions are generated using calculated associative connections and behaviors. Effect analysis is done simultaneously.

The authors emphasize the personal intent nature of knowledge at engineering in [12]. Moreover, a decision is often controlled by combined intent. In other words, intent is composed by intents of several humans. A decision that seems to be a simple one may have complex human and knowledge background. Decision on single dimensions by engineers who are responsible for them may apply intent and knowledge information from scientists, standards, legislation, local instructions, customer demands, and decisions of engineers on a higher level of hierarchy. Engineers participating in decision chains apply knowledge from other sources through a filtering by personal, corporate or even official intent.

Application of extended knowledge ware in order to store corporate knowledge and related information is explained in Figure 7. Decisions are supported by behavior analysis, creation of views in product data, and combination of intents. Knowledge ware is developed by human controlled decision support procedures, directly by humans, and outside linked sources. Knowledge ware items cover conventional knowledge, intent combinations, situations for behaviors, effectivity information for attributes and objects, type of effects of changes, as well as information about humans and outside links.

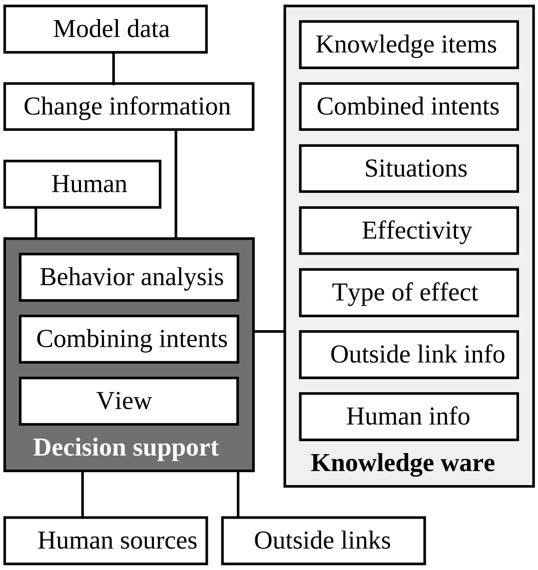

Figure 7
Development of knowledge ware

5 Characteristics of a Virtual Space

Methodological elements of change processing are outlined in Figure 3 as thematically separated development, behavior, interface, and learning sectors. This definition serves integration of different aspects. In the development sector, object descriptions and capabilities of modeling are developed during product development. In the behavior sector, situations are generated, behaviors are analyzed, and rules are applied. Behaviors are created as objective descriptions at the development sector. Interface sector has the ability to receive and reacting effects. In the meantime, patterns and rules are learned for later application.

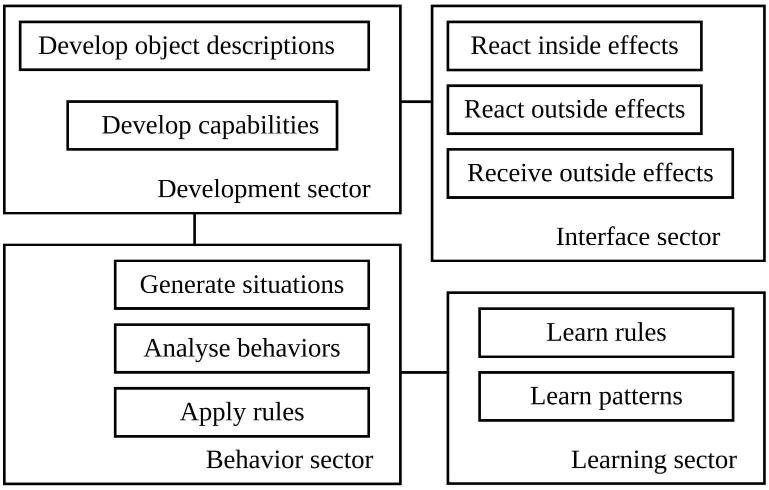

Figure 8

Methodological elements of change processing

The proposed extended product modeling can be considered as a virtual intelligent space (Fig. 9). In this case, theory and methodology of intelligent spaces can be applied and high-level knowledge based solution can be established for product development. Development effects are generated by development function of an actual space. On the other hand, actual space generates demands for its development as a consequence of inside or outside attempts for its change. This separated development procedure ensures a protection of an intelligent space against undesired modifications. Empty spaces, imported subspaces, and interfaced subspaces are available for space development. Practically, a virtual space is a connected description of a purposefully defined set of modeled psychical and logical objects. It is always has an actual state, responses for attempts for changes, and sensitive to changes in the outside world.

Development of the proposed modeling environment into virtual intelligent space requires an analysis of modeling and intelligent space characteristics. This is one of future works planned by the authors.

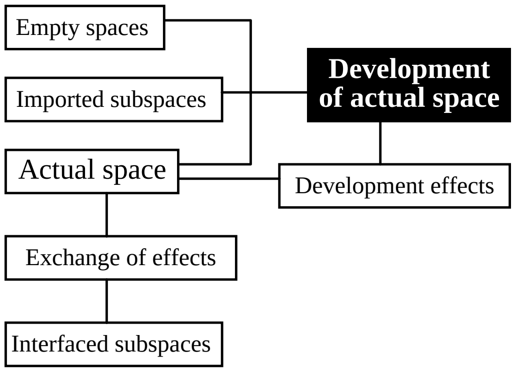

Figure 9
Concept of virtual intelligent space for engineering

Conclusions and Implementation

An integrated application of well-proved shape centered modeling of products, advance human-computer communication, and behavior based change management is proposed in this paper in order to enhance human decisions in development and application of complex product models. First of all, closely related engineering objects are grouped and associative definitions are applied to reveal affect zones for changes of individual engineering objects. The proposed method is based on behaviors as representations of engineering objectives.

The method is intended for recent professional PLM systems. Consequently, it must be adapted to information and modeling procedure environment of existing software. Following this, development can be done according to local demands by using of open structure software development tools in PLM systems.

An experimental space is under development and construction at the Laboratory of Intelligent Engineering Systems (John von Neumann Faculty of Informatics, at the Budapest Tech). Future research is planned around of this pilot system. It involves emphases on analysis of intelligent space processes, as well as their elements and connections.

References

[1] Kim, Y.S., Wang, E., “Recognition of Machining Features for Cast then Machined Parts,” *Computer-Aided Design,* Vol. 34, No. 1, (2002): p. 71-87

[2] Zha, X.F., Du, H., “A PDES/STEP-based Model and System for Concurrent Integrated Design and Assembly Planning,” *Computer-Aided Design*, Vol. 34, (2002)

[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] Yasuhisa Hasegawa, Toshio Fukuda, "Motion Coordination of Behavior-based Controller for Brachiation Robot", In *Proceedings of the 1999 IEEE International Conference on Systems, Man, and Cybernetic, Human Communication and Cybernetics*, IEEE, Tokyo, Vol. 6, 896-901, 1999

[5] Vokorokos, L.: Digital Computer Principles. Typotex Ltd. Retek 33-35, ISBN 96-39548-09-X., Budapest, p. 230, 2004

[6] M. Caccia, P. Coletta, G. Bruzzone, G. Veruggio, "Execution Control of Robotic Tasks: a Petri Net-based Approach," *Control Engineering Practice*, Volume 13, Issue 8, August 2005, pp: 959-971

[7] J. A. Domínguez-López, R. I. Damper, R. M. Crowder, C. J. Harris, "Adaptive Neurofuzzy Control of a Robotic Gripper with On-line Machine Learning," *Robotics and Autonomous Systems*, Vol. 48, Issues 2-3, 30 September 2004, pp 93-110

[8] Da Ruan, Changjiu Zhou, Madan M. Gupta, "Fuzzy Set Techniques for Intelligent Robotic Systems," *Fuzzy Sets and Systems*, Vol. 134, Issue 1, 16 February 2003, pp: 1-4

[9] Paul F. M. J. Verschure, Philipp Althaus, "A Real-World Rational Agent: Unifying Old and New AI," *Cognitive Science* Volume 27, Issue 4, July-August 2003, pp: 561-590

[10] József Tick, "Software User Interface Modelling with UML Support," in *proc. of the IEEE International Conference on Computational Cybernetics, ICCC 2005*, Mauritius, 2005, pp. 325-3

[11] Hermann Gy., "Geometric Modeling in Reconstructing Surgery, in *Proc. of the 6th International Conference on Intelligent Engineering Systems 2002 (INES 2002)*, Opatija, Croatia, 2002, pp. 379-382

[12] L. Horváth, I. J. Rudas, "*Modeling and Problem Solving Methods for Engineers* ", ISBN 0-12-602250-X, Elsevier, Academic Press, 2004

[13] L. Horváth, I. 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

[14] L. Horváth, I. J. Rudas, G. Hancke, "Feature Driven Integrated Product and Robot Assembly Modeling," in *Proc. of the The Seventh International Conference on Automation Technology, Automation 2003*, Chia-yi, Taiwan, 2003, *pp.* 906-911

[15] L. Horváth, I. 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, 2001, pp. 273-278

[16] L. Horváth, I. J. Rudas, C. 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

[17] L. Horváth, I. J. Rudas, "Possibilities for Application of Associative Objects with Built-in Intelligence in Engineering Modeling" in *Journal of Advanced Computational Intelligence and Intelligent Informatics*, Tokyo, Vol. 8, No. 5, pp. 544-551, 2004