New Design Objective and Human Intent-based Management of Changes for Product Modeling

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Abstract: This paper is concerned with the evaluation of effects of modeled object changes at development of product in virtual space. Modeling of engineering objects such as elements and structures of products, results of analyses and tests, processes for production, and customer services has reached the level where sophisticated descriptions and modeling procedures serve lifecycle management of product information (PLM). However, effective utilization of highly associative product models is impossible in current modeling because techniques are not available for tracking and evaluation of high number of associative relationships in large product model. The author analyzed the above problem and considered inappropriate organization of product information as its main cause. In order to gain a solution in current modeling systems, a new method is proposed in this paper for change management. In this method, joint modeling of design objectives and human intent is applied for shape-centered products. As background information for the proposed modeling, paper discusses research results in change management for product development in modeling environments. Following this, integrated modeling of closely related engineering objects is proposed as extension to current industrial PLM systems. Next, design objective driven product change management is detailed. Finally, virtual space is outlined as a possible advanced application of the proposed change management with the capability of representation of human intent.

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

1 Introduction

The success of industrial product modeling has led to highly integrated engineering systems called as product lifecycle management (PLM) systems. Design, analysis, production planning, marketing, and customer service applies the same software and data base system. PLM systems are being moved into Internet portals and they act as integrators in extensive project work at extended companies. This new style of engineering is based on integrated description of engineering objects in product model. While high-level software tools process product models, effective communication between human and modeling procedure is not possible in current industrial modeling systems. Product models reached a complexity where application of conventional human-computer procedures does not provide means to survey consequences of a change in the highly associative product information. Engineers suffer from low-level support of decision-making processes. As a consequence, they do not able to survey huge number of related decisions, human intents, knowledge, and legislations.

The contribution of this paper is a new method for human – computer communication at decisions in engineering. Two essential model entities are introduced as means for representation of design objectives and human intents in their background. Based on these new elements of product model, new process is proposed for handling of changes of modeled objects during development and application of products. The proposed method is highly relied upon earlier researches by the author and other researches in product modeling and intelligent computing.

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2 Background

Product modeling can be summarized as definition, generation, and handling information for engineering activities during the entire lifecycle of products. Product model is heterogeneous because it describes different engineering objects such as components, analysis models, manufacturing processes, production schedules, and so on. For a consistent product model, it is essential to know the variation of modeled object parameters due to variations in other parameters. Typically, an engineering object parameter depends on high number of parameters of other objects as well as specifications. A great deal of study has been devoted to identify characteristics of engineering objects and current techniques in engineering modeling [1].

Important advancement towards efficient human-computer interaction (HCI) was application of form features at the definition of shape of mechanical parts during the nineties. Mechanical parts have shape-centered characteristic because any other information can be mapped to shape information. The author introduces research results for the application together with proven shape-centered modeling. Several researches were considered. The most relevant ones are cited as follows.

Form features are defined during construction a shape or recognized on a previously created shape. A method is given for multipurpose application oriented recognition of features in [2]. Other important area of model development is integrated product modeling for concurrent engineering. Typical product related engineering activities are integrated in concurrent integrated engineering in [3]. Reference models, resources, and application protocols are essential tools for the definition of integrated product models [4]. Description of behaviors of products in models represents initial efforts towards intelligent engineering modeling [5]. Broadening the application of computer systems at engineering was stimulated by advancements in digital computer principles [6].

In [7] Petri net is proposed as representation for design and implementation of an execution control, which, through suitable graph-search algorithms, generates sequences of task activation and deactivation operations, which execute the desired commands maintaining the system in admissible configurations. Environment composed by known and unknown elements are typical at certain applications. Availability of machine learning is essential in the handling of unforeseen environmental conditions. Robot controller can learn on-line about its own capabilities and limitations when interacting with its environment. A method is proposed in [8] 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 great importance [9], among others at reduction of rule sets for the representation of corporate knowledge. Authors of [10] 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 [11] examined how UML, as the most widespread modeling tool for 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 [12].

Researches with participation of the author are cited as antecedents of the contribution in this paper below. The authors analyzed possibilities for extended application of the feature principle, adaptive processes and associative object definitions [13]. Other relevant researches are as follows.

- Application of product and other engineering object behavior definitions and adaptive actions in order to enhanced decisions [14].
- Modeling of human intent as background of engineering decisions [15].
- Integration of human intent descriptions in product models [16].
- Modeling for the handling of changes of engineering objects [17].

3 Closely Related Sets of Engineering Objects

The proposed change management requires modeling of human intent and product behaviors. This is evident because humans define model information according their intent and the aim of product development is realization of design objectives as behaviors. Moreover, humans apply knowledge according to their intent or execute intents of other humans of higher hierarchical position. For this purpose, three extensions to modeling in current industrial PLM systems are proposed (Figure 1) as follows.

- Integration of descriptions of closely related engineering objects.
- Extensions to object descriptions for human intent, associative object connections, adaptive actions, and product behaviors.
- Extensions to modeling procedures for the handling of HCI specific views in product data, collaborative connections, adaptive actions, and engineering specific browsing.

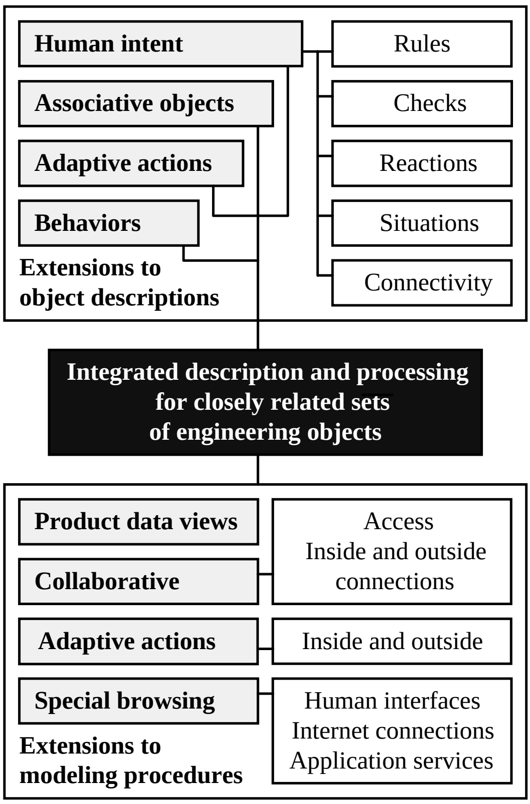

Figure 1

Essential approach to product modeling

Associative definitions connect objects inside and outside of a set of engineering objects. Human intent is described by using of one of the well-proven knowledge representations. Engineer-friendly representations are preferred such as rules, checks, reactions, situations, and networks.

Functional sectors of product information are connected, as it is outlined in Fig. 2. Outside world includes objects outside of an actual set of engineering objects. Changes of engineering objects are sensed from the outside world through associative object connections then are recorded as senses. Product model integrates object descriptions. Object descriptions are connected with behaviors. Behaviors are in close connection with knowledge for human intent and objectives for product development. Fulfilling the specified behaviors needs actions on inside and outside engineering objects.

In accordance with essential connections in Figure 2, essential modeling procedures are outlined in Figure 3. Information exchange processes serve communication between a set of closely related engineering objects and the world outside of it. Associative object definition manager is in connection with creation of model entities and action manager. Associative definition builder establishes new connections for behavior analysis driven action definition. Action definition initiates creation or modification of product 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. Humans control HCI procedures. Internet portal organizes group work of engineers and provides means for collaboration amongst humans independent of geographical position.

4 Product Change Management for Design Objectives

Any attempt for changing any modeled product or product related engineering object must be evaluated for consequences on all associative objects before deciding its acceptance or rejection. This evaluation requires tracking along chains of associative objects in the product model. In this context, any modification of a product for its development, variant creation and correction is considered as change. Engineering on a product is a sequence of changes. Evaluation of a change analyzes appropriateness of a new proposed parameter value of a modeled engineering object for appropriate design objectives. This passive evaluation can be replaced by active evaluation to calculate parameters of modeled objects that results in behaviors in accordance with specified engineering objectives. Change of an engineering object parameter may affect one or more behaviors of the same and associative engineering objects. The author introduced the concept of change affect zone (CAZ) in order to define the set of potentially affected engineering objects for change of an engineering object,. CAZ of an engineering object includes a set of engineering objects that may require modifications as a consequence of its change.

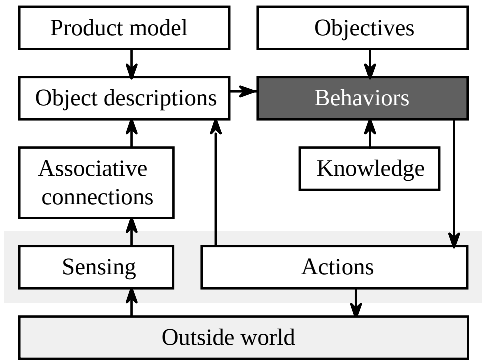

Figure 2

Essential connections of model information

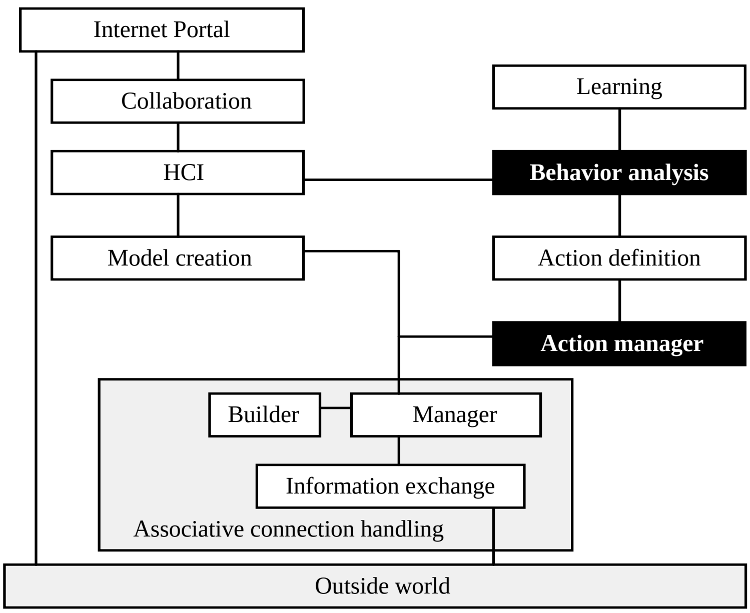

Figure 3

Essential modeling procedures

A behavior of an engineering object is defined by a set of its attributes. Any combination of values of these attributes results in a behavior with allowable or not allowable characteristics. Required or allowed combinations of parameters affecting characteristics of a behavior are specified as situations. A situation is defined by a set of attribute values called as circumstances. Specifications of behaviors as design objectives for an engineering object consider customer demands, technical requirements, experiences, standards, legislations, and personal intents.

The author applies an extended definition of behavior for engineering objects. Figure 4 shows an example for the extension from shape centered product modeling. Characteristics of the shape became important factor during the past decade. Design objectives for shape, placing, continuity, and locality of a swept surface are specified by four behaviors, accordingly. Shape behavior is defined by situation for shape control. This situation comprises attributes of the swept surface serving modification of the shape. Other behaviors characterize placing of surface in a solid shape and its structural environment, continuity at its connections, and parametrically controlled local characteristics of the surface.

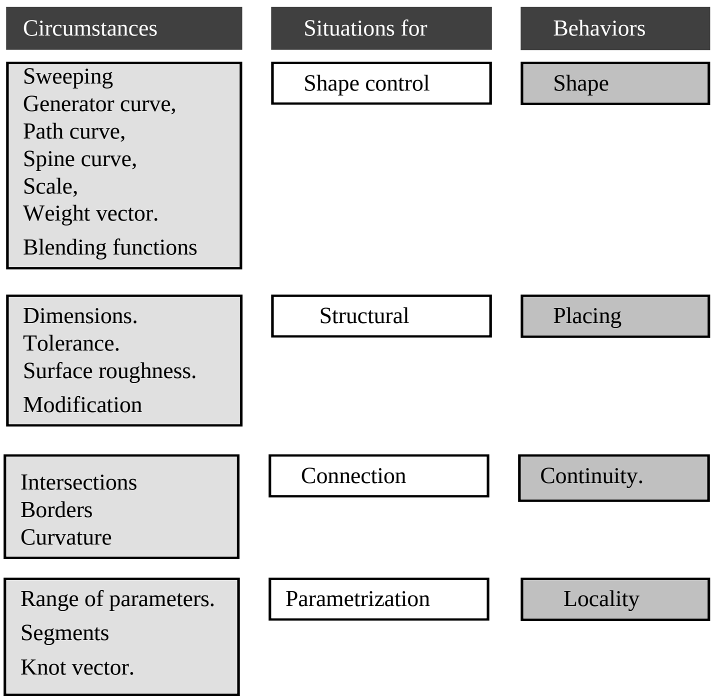

Figure 4
Example of surface behaviors

Essential management of object changes is outlined in Fig. 5. A set of closely related engineering objects are integrated in a complex engineering object. This object constitutes the inside world. All other engineering objects are in the outside world. Configuration of inside world is more or less flexible according to actual measures in the engineering organization. Model of a complex engineering object includes information for elements, composition, situations, associative relations, and behaviors. Change management is supported by affect analysis. It handles adaptive actions. An adaptive action carries information for a change and may have four states. Change management receives information from interfaced humans and procedures about proposed and accepted changes. Its communication with outside world is about attempted and accepted changes. Change management generates new adaptive actions as consequences of proposed, attempted, and accepted changes. Adaptive actions with received, attempted and generated states are considered as conditional ones. Accepted adaptive actions are executed by inside and outside procedures.

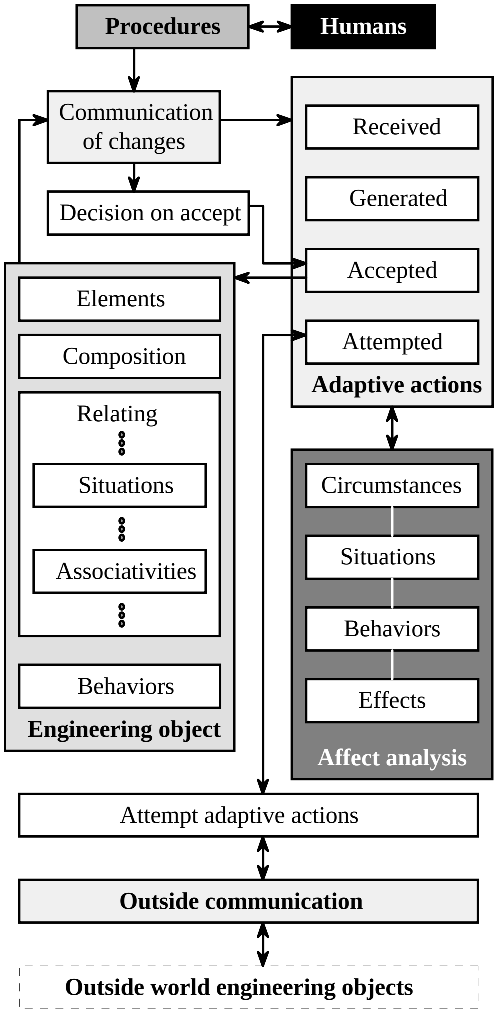

Figure 5

Management of changes of modeled objects

During acceptance procedure, changes are analyzed for their affects on attributes and behaviors of associative engineering objects. New adaptive actions are generated and affect analyzed along chains of associative engineering objects.

Acceptance procedure is continued during the entire product development and it is under control of responsible humans. Engineers have much more chance to find a conflict free solution than in conventional modeling. Change management acts as advanced navigator rather than design automata. The consequences of changes are often calculated directly, as modifications of elementary or composition objects. Sometimes simple changes are abandoned due to improper changes of behaviors. Alternatively, behaviors can be changed.

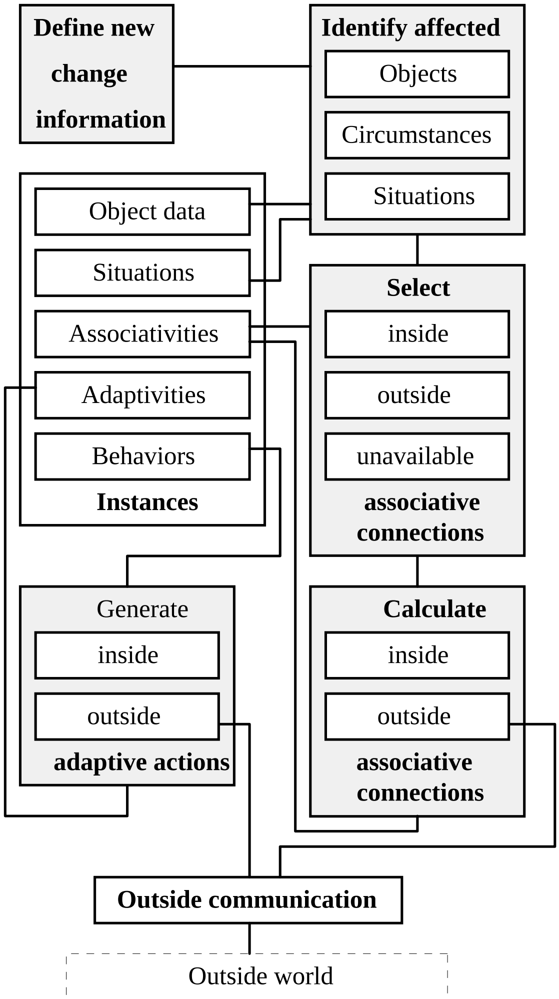

Figure 6

Processing of change information

Some details of change management are shown in Figure 6. Instances of generic descriptive object entities, situations, associative connections, adaptive actions and behaviors are defined. Process is briefed in the following.

- Engineering objects, circumstances, and situations are identified for behavior analysis.
- Inside, outside and unavailable associative connection definitions are selected for the identified model entities.
- Values for inside and outside associative connections are calculated and adaptive actions are generated.

Unknown associative connections must be considered and possibly defined by responsible humans.

The above discussion interpreted the product development as a series of decisions on changes towards product with specified behaviors. Decision support is summarized in Figure 7. It is connected to human sources, modeling procedures, and outside world items. Behavior analysis, creation of views, combination of intents, and change management are essential methods. Decision process uses conventional object data and extensions for the proposed modeling. These extensions are situations for behavior analysis, combined intents, effectivities for views, and types of effects. Additional items carry information about humans and outside links.

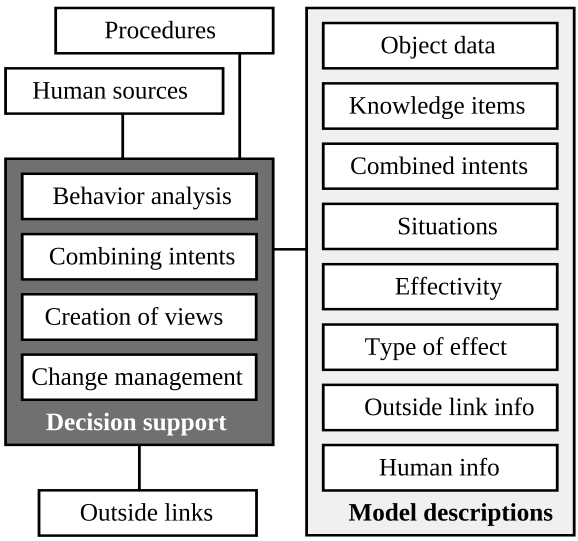

Figure 7

Support of decision-making

Decision on attributes of an engineering object may have complex human and knowledge background. It is often controlled by intent of two or more humans. Responsible engineer considers intent from research results, standards, legislation, local instructions, customer demands, and decisions of engineers on higher levels of hierarchy. At making these decisions, intents should be combined.

5 Concept of Virtual Space

Change management in the previous sector of this paper can support activities in a virtual space that is capable to accommodate computational intelligence as representation of human intent. Product model is developed in a virtual space where a development sector is responsible both for development of product descriptions and modeling capabilities (Figure 8). Other sectors of a virtual space are responsible for behavior, interface, and learning related activities. In the behavior sector, situations are generated, behaviors are analyzed, and rules are applied. Behaviors are created as engineering objectives under control of the development sector. Interface sector has the ability to receive and reacting effects. In the meantime, patterns and rules are learned for later application.

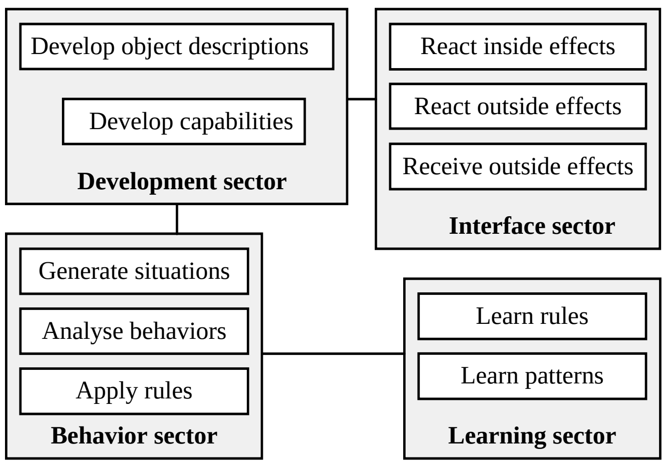

Figure 8
Sectors in virtual space

Virtual space characterized by actual state, responses for change attempts and sensitive to changes in the outside world. Development sector constructs space by using of subspaces (Figure 9). A subspace is defined for a set of closely related engineering objects as it was explained in sector 3 of this paper (Figure 1). Empty and imported subspaces are available for development of an actual space. Development effects are generated by adaptive actions. Separated development protects the virtual space against undesired modifications. Effects are exchanged with interfaced subspaces.

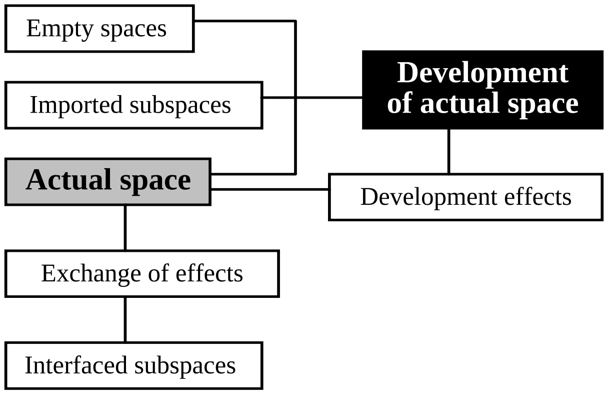

Figure 9
Development of virtual space for engineering

Conclusions and Implementation

Very complex structure of associative connections amongst high number of engineering objects in product models cause serious problems at management of frequent changes during development of the modeled product and its production. Solution for this problem is urgent because product modeling has been extended to definition, generation, and handling all information for engineering activities during entire lifecycle of products. Consistency of the heterogeneous product model requires information about the variation of modeled object parameters due to variations in other parameters. The paper introduced a possible solution in which three extensions are proposed for modeling in current industrial PLM systems. Extensions are integration of descriptions of closely related engineering objects, new model entities for description of engineering objectives, associative relations, and adaptive actions, and new methods for change management.

Method to reveal change affect zone (CAZ) for changed objects and tracking chains of associative engineering objects are essential elements of the proposed modeling. Change management can support activities in a virtual space that can accommodate computational intelligence as representation of human intent. In this case, product model is developed in a virtual space where a development sector is responsible both for development of product descriptions and modeling capabilities. In addition, sectors are defined in the virtual space for behavior, interface, and learning related activities.

An experimental virtual engineering space is under development at the Laboratory of Intelligent Engineering Systems (John von Neumann Faculty of Informatics, Budapest Tech). It integrates subsystems in order to establish a typical PLM environment. Leading PLM software is applied for digital product definition, analysis, intelligent computing, product data management, multi-site type of group work, and Internet portal purposes.

References

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

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

[3] 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)

[4] 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

[5] 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

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

[7] 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

[8] 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*, Volume 48, Issues 2-3, 30 September 2004, pp. 93-110

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

[10] 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

[11] 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

[12] 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

[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