Proceedings of the 5th WSEAS Int. Conf. on SIMULATION, MODELING AND OPTIMIZATION, Corfu, Greece, August 17-19, 2005 (pp604-609)

Features for Behaviors, Adaptivities and Processes in Modeling of Industrial Robot Systems

IMRE. J. RUDAS and LÁSZLÓ HORVÁTH
John von Neumann Faculty of Informatics
Budapest Tech Polytechnical Institution
Népszínház u. 8., Budapest H-1081
HUNGARY

Abstract—The authors report a research about environment adaptive model objects and their application in unified and comprehensive modeling of an industrial robot system. The proposed method makes it possible to utilize modeling and models that are applied in leading industrial CAD/CAM systems. The main essence of the reported work is application of behavior and adaptivity features in a shape-modeling environment where all shapes on all parts of a robot and product manipulated by them are described by application oriented form features. The task is an integration of product description, modification and analysis with robot system and robot process description in a full associative system. The authors introduce an approach and some methodologies for this special purpose modeling. Implementation of the proposed methods is conceptualized as integration of commercial program and robot products. The integrator is a proposed special purpose model that can be realized by using of open architecture development tools as available in industrial CAD/CAM systems. The paper outlines the present situation and the proposed modeling. Then role of behaviors and source of human originated knowledge are discussed. Following this, extended application of the feature principle in the proposed modeling is detailed and illustrated by the example of part placing.
Key-Words: product modeling, behavior based modeling, modeling by features, robot control in manufacturing, large-scale integration of models.

1 Introduction

Application of robots in industrial systems supposes integration of robot process with product modeling and local knowledge management. This first step to integration of robot related engineering into product lifetime engineering in portal based and advanced product data management assisted global group work of engineers is still in the stage of research. The present integration of product and robot system modeling is in the level of geometry. This is a problem because engineers work with engineering problem related shape aspects called as form features. Geometry is mapped to form features so that engineers handle form features, while modeling system calculates by using of geometric model. The authors think the cause of this problem as the lack of feature like entities for the purposes of handling of robot processes, changes together with their consequences as well as behaviors for various simulations and analyses.

The proposed modeling applies some results from earlier works by the authors, in application of features to replace geometry-oriented robot programming [1], [2]. Behavior based analysis [3] and application of agents [4] represent initial stage of intelligent modeling. Product modeling by using of reference models, modeling resources and application protocols has been established in the STEP modeling standardized by the ISO. The proposed modeling can be implemented in STEP environments. This is the way to affordable application of the results introduced in this paper.

Other related works deal mainly with issues of separated important problem complexes as description of shapes and trajectories in robot work space, strategies of assembly and disassembly, and assembly path planning. Comprehensive environments are created for definition of assembly for computer systems. Solid models are used at feature recognition. In [5], an approach is applied to generate a graph of collision free paths, in which the nodes are the milestones and the edges represent simple paths. Several methods for optimal definition of robot trajectories suppose modeling and analysis of the shape system [6]. Finally, introduction of task oriented robot programming was one of the important steps towards extended application of robots in factory automation.

The authors elaborated an approach to integrated model objects with the capabilities to self-development by new elements, self-modification, and modification of any related objects. These capabilities of model objects rely on high-level definition of inside and inter-object associativities, adaptive control of object descriptions, and behavior based evaluation. Mutual modifications of model entities are initiated by changes at well-defined circumstances.

The authors analyzed the application of intelligent computing methods in behavior based engineering modeling [7]. The proposed model includes information about earlier decisions as design intent. Modeling of background of human activities in engineering modeling by the authors [8] prepared application of design intent modeling for definition of the proposed model objects.

Implementation of the proposed methods is conceptualized as integration of commercial program and robot product. The integrator is the proposed special purpose model that can be realized by using of open architecture development tool of industrial CAD/CAM systems.

The paper outlines the present situation and the proposed modeling. Then role of behaviors and source of human originated knowledge are discussed. Following this, extended application of the feature principle in the proposed modeling is detailed and illustrated by the example of part placing.

2 Adaptive Modeling for Robot Systems

Robot process planning functions in present CAD/CAM systems apply geometric modeling. Robot processes have not been integrated with the prevailing form feature based part modeling. Description of part geometry is applied as source of shape information for definition of gripping, target position, and path and for analysis of collisions (Fig. 1). Robot systems are modeled by part geometry and kinematics. This approach supports only communication of geometric information between part modeling and robot programming. Engineers are forced to use geometric model entities instead of engineer defined entities.

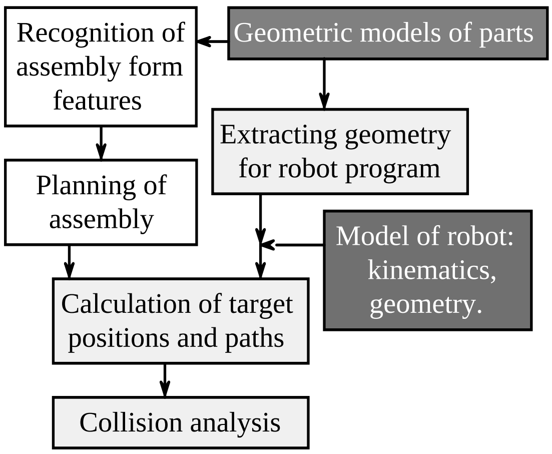

Fig. 1 The present geometry based approach to robot programming

The authors apply a different approach to solve robot programming problem by engineering related entities replacing the conventional geometry based solution (Fig. 2). Feature based robot process model is introduced that is associative with shape models, robot oriented form features for the description of all parts in the system, and various associativity definitions between pairs of form features in robot and handled parts during robot processes. Models of the handled parts of the product and parts of the robot system *MP1-MPn* are described as sequences of shape modifications represented by topology and geometry. At definition of form features for robot assembly, the sequence of shape modifications for design of a part is reordered then shape modifications are integrated or detached. Form features that have not any affect on the robot process are suppressed. Engineers work with attributed, robot process related form features while geometric model representations are mapped to form features and available for geometric calculations. Form features in part models are interconnected by associativity features for part placing, for example for the purpose of modeling of robot assembly. A unified feature based and application oriented modeling has been conceptualized for the whole system.

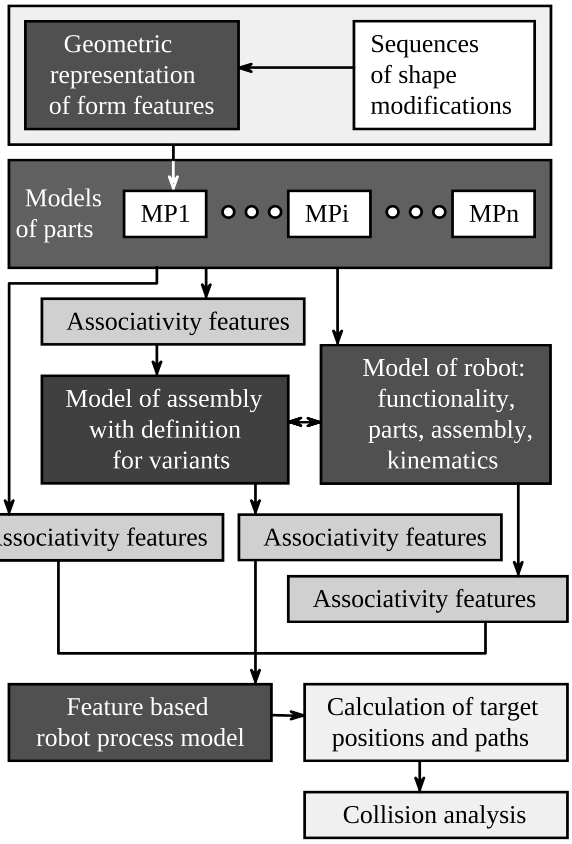

Fig. 2 The proposed model of the robot system

As extending of feature sets as available in advanced industrial modeling systems, behaviors, adaptivities, 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). 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. 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 attempting 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.

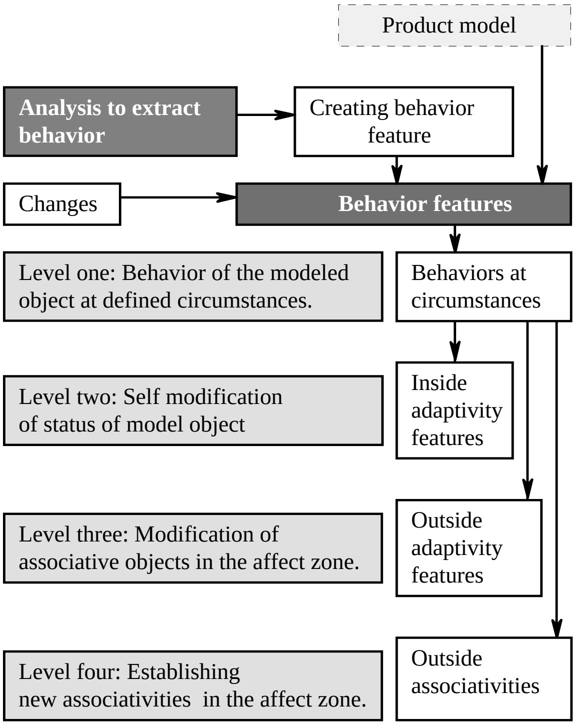

Fig. 3 Multilevel approach to modeling

General architecture of an integrated model object can be followed in Fig. 4. Characteristics of the object are defined by using of generic object definition then modified during the life of the object by self-adaptivity management and definition of inherited characteristics. Creation and handling of elementary object, structure and relationship representations are controlled by object characteristics. Description and analysis of behaviors are supported by knowledge representations. World outside of the model object is interfaced by the functional group of outside links. It interprets the affects from outside and towards other 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. 5). Behaviors of the modeled object are elaborated by using of situations composed by 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.

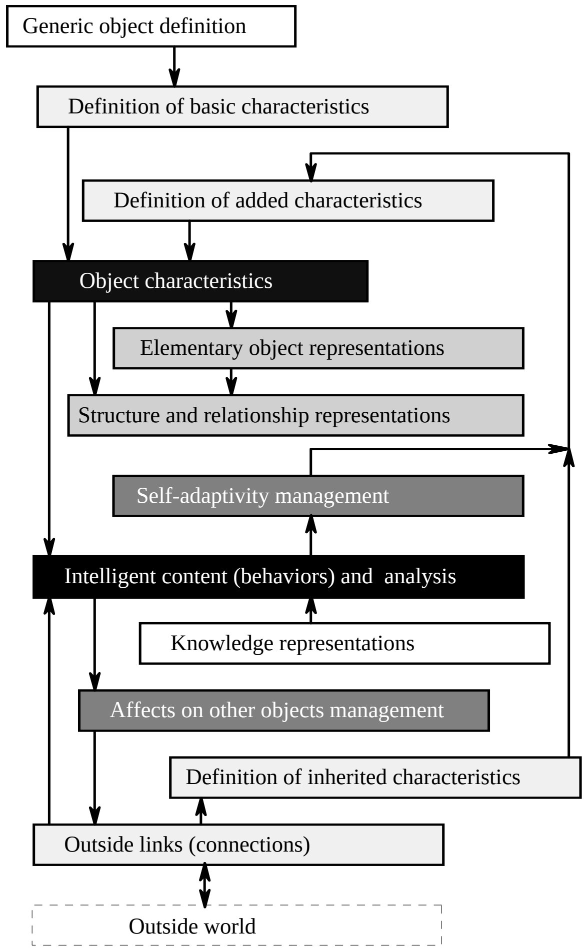

Fig. 4 Information flow in an integrated model object

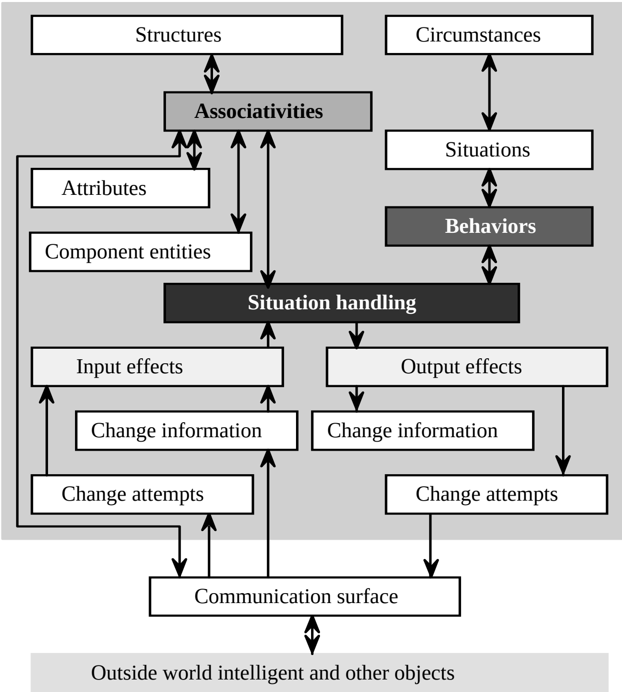

Fig. 5 Handling of situations and communications

3 Behaviors in Placing of Parts by Robot

In process-oriented model of a mechanical system, all entities can be defined and handled in recent industrial CAD/CAM systems except for behaviors. Integration of behaviors is one of the main contributions of the methodology proposed by the authors in this paper. Elementary and relationship features are defined by engineers or recognized by procedures then collected in and retrieved from feature libraries. During construction of a model, elementary features are defined. Then they are used at definition or modification of structure features. In other cases, elementary features are defined using structure features. Behavior features produce intelligent assistance for definition of elementary, structure and relationship features. Associativity chains are defined along connections of features. Knowledge and adaptivity features may be integrated or attached to the system at any human, procedure, and data base communication. They are propagated along associativity chains. It can be said that knowledge features have the capability to modify any other features. Modeled world outside of the world described by a model object has data, knowledge, adaptivity and human communications with the model object. Humans must have responsibility-based privileges.

Behaviors are originated from customer demands, requirements by engineering activities, experiences and personal intents. Essential behaviors are shape, part, manufacturing, assembly, kinematics, and appearance related. They answer behaviors of a modeled object for different circumstances and also change behaviors according to changes of object instances.

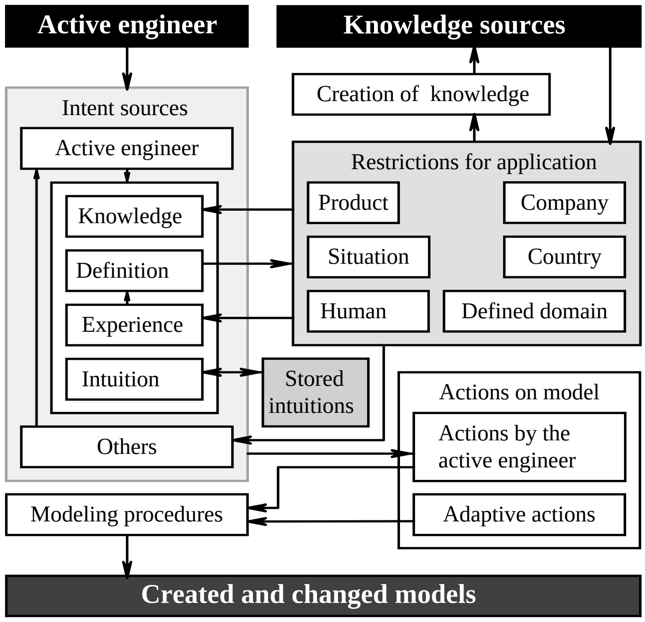

Fig. 6 Human intent originated knowledge

It is an essential characteristic of engineering that any task is at the responsibility of an engineer or several engineers share responsibility. In this model, the engineer who is responsible for the actual task is called as the active engineer. 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 an application of standard, law, 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. 6). 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.

4 Form Features in Robot Assembly Model

Model of a product including part models, placing of parts in assemblies is often communicated with its downstream applications through data exchange. Planning and control of robot processes are important downstream applications. Downstream modeling systems often offer different modeling capabilities and sets of entities. The required model data conversion can be controlled by design intent information. Intent information is then used by product model application procedures or communicated to active engineers.

The proposed integrated model organizes computer description of all of the involved shape and process objects. At a stage of an assembly process, a part is being placed. Other parts are in the semi-finished assembly or are waiting for placement. Several parts of the robot are in fixed or changing positions in the workspace of the robot. Parts are described by shape definitions. The assembly task is defined by robot assembly process. Associative shape and process definitions are connected by relationship definitions.

Prevailing geometric model representation of shape by its boundary consists of topology and geometry. This structure serves as representation of form features. A geometric relationship relates surfaces or lines by their coincidence, contact, distance, or angle. To change from geometric based description to feature based one in definition of part placing, product assembly relationship feature is introduced with a three-leveled structure. This structure relies on similar principle as form feature definitions. Fig 7 shows the example of *Placing of a prism* application relationship feature, which is defined on the *level 1*. Three contact geometric relationships are mapped to the relationship feature *C1* on level 2. Relationship feature *C1* is defined between form features *FF1* and *FF2*. Geometric relationships *C11*, *C12* and *C13* are defined between pairs of flat surfaces on level 3. Description of these surfaces can be accessed following the topology structure in the boundary representations. Face *F1* is connected to the topological structure of the form feature *FF1* and to the topological structure of the part by closed loop of topological edges *E1*, *E2*, *E3* and *E4*.

Similarly to the product assembly relationship feature definition, robot process configuration relationships are defined on three levels (Fig. 8). On the *level 1*, robot configuration relationship application feature *ACF1* is defined for application, similarly to product assembly relationship feature. Its type in the example is *Part and assembly of product*. It defines relationship between the part being placed and a part in the existing stage of the assembly unit. A part in an assembly of a product can be defined as a unit if individual parts consisting of it do not affect robot assembly. However, because geometry is mapped to form features on parts, a complex part should be mapped to the individual parts composing it. A single relationship in the case of example on Fig. 8 is defined on the level of form features as robot configuration relationship feature *RCF1* on the *level 2*. It describes the constraint of *contact is not allowed* between a pairs of form features *FF3* and *FF4*. flat surfaces. On *level 3*, geometric relationships RG1 and RG2 relates two pairs of flat surfaces (*FS11* and *FS12, FS21* and *FS22*).

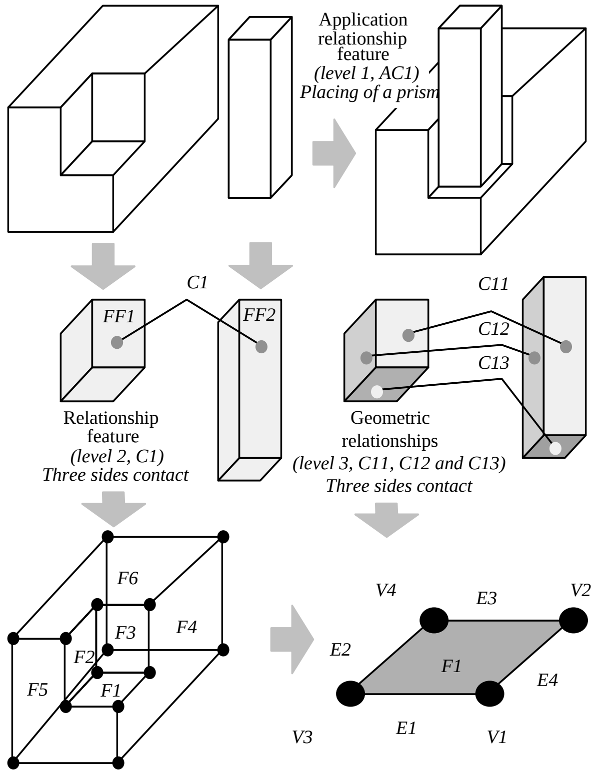

Fig. 7 Feature definition for part placing

The necessary calculations are done using topological definitions in the related boundary representations. The relationships connect the proper elements in the topologies of the two parts then geometry is revealed by their mappings to the related topological entities. This method constitutes the main essence of the proposed integration in shape modeling.

Capacity issues restrict application of resources as engineers, model entity types, parameter ranges and values, solutions, methods and facilities. 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 are stored or communicated intents contradicting intents that enforce new or modified decisions. 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. It is one of the most important elements of the proposed modeling. Resolution by hierarchy of intent holders should be avoided. However, it is normal practice in present day engineering. Capability driven change of intents is forced by real world circumstances. On the other hand, consideration of some new resources may produce solutions that are acceptable for all holders of conflicting intents.

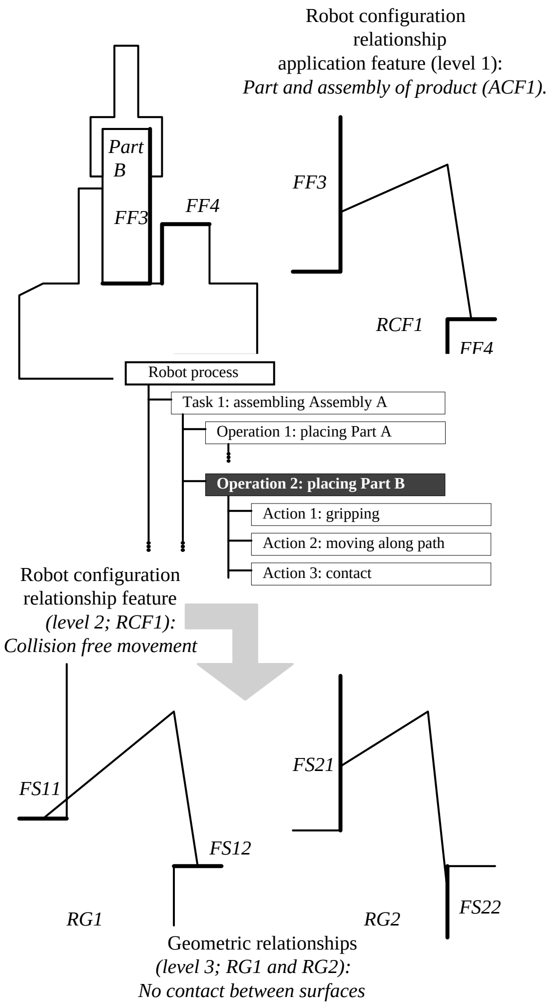

Fig. 8 Example for robot process configuration feature

5 Conclusion

The authors introduced a modeling method for enhanced application of advanced engineering modeling in robotics. The proposed modeling is intended to give concept and methodological background for the application of an extended feature concept in integrated product and production modeling for downstream applications at planning and control of robot processes. For engineering purposed description of objects, analysis and handling of product and production environment modification, extended form and relationship features, behavior features, and adaptivity features are proposed by the authors. The paper discusses different aspects, situations, and configurations at creation and communication of modeled information. It can be concluded, that model that the proposed modeling can be implemented as an extension of recent industrial CAD/CAM systems. It also and can contribute to an organized introduction of computational intelligence in robot related engineering.

6 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] 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.

[2] László Horváth, Imre. J. Rudas, "Intelligent Computer Methods in Behavior Based Engineering Modeling", Proceedings of the 2002 IEEE International Conference on Systems, Man and Cybernetics, Hammamet, Tunisia, pp: WP1F2.

[3] 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, VolumeVol. 6, 896-901, 1999.

[4] 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.

[5] D. Hsu, J.C. Latombe, and R. Motwani, "Path Planning in Expansive Configuration Spaces", Journal of Computational Geometry and Applications, Volume 9, No. 4-5, pp: 495-512, 1999.

[6] E. Freund, D. Pensky, R. Wischnewski, COSIMIR "Open 3D Simulation System for Production Automation Processes", Proceedings of the RAAD 2001, 10th International Workshop on Robotics in Alpe-Adria-Danube Region Vienna, Austria, 2001, pp. 16-18.

[7] L. Horváth, I. J. Rudas, "Active Description of Engineering Objects for Modeling in Extended Companies," *in proc of the 2004 IEEE International Conference onSystems, Man & Cybernetics, SMC 2004*, ISBN 0-7803-85675, 2004, pp. 3312 – 3317.

[8] László Horváth, Imre J. Rudas, "Modeling of the Background of Human Activities in Engineering Modeling", In Proceedings of the IECON' 01, 27th Annual Conference of the IEEE Industrial Electronics Society, Denver, Colorado, USA, pp. 273-278.