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Information Content Modeling-based Recognition of Change Chains in Product Models

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Abstract: Future advancements in simulation and decision assistance require representation of much more information about dependencies for calculation of parameters of modeled objects and evaluation of consequences of changed values of those parameters than it is possible in recent industrial modeling systems. As a contribution to product modeling with enhanced decision assistance, the authors introduced the concept of engineering object parameter dependent affect zone for the restriction of search space of dependencies into an actual subspace. In order to support the related decision making, description of information content of dependencies and introduction of concept of engineering object for description of any physical or logical modeled objects in lifecycle of product are proposed as new methods. After an introduction to the proposed modeling, the authors cite and explain the related research and their own research in related topics. Following this, change affect zone (CAZ) of an engineering object parameter is introduced to define a restricted search space in the graph for consequences of an object change in product model. Next, a comparison is given for better understanding of data and content orientations of product model and modeling. Finally, extension to industrial PLM systems in order to realize the proposed modeling is outlined.

Keywords: Product lifecycle management, product modeling, decision assistance, information content based product modeling, change affect zone

1 Introduction

Despite the high level of virtual technology involved, product modeling systems can not cope with increasing demands for decision assistance in the new environment of extended companies. The main cause of this situation that higher level of automation in simulation and decision assistance would require representation of much more information about dependencies for calculation of parameters of modeled objects and evaluation of consequences of changed values of those parameters than it is possible in recent industrial modeling systems.

As a contribution to solution for this problem, authors have developed a structural description of dependencies amongst engineering objects in product model. Two focus problems of this work were high number of unstructured dependencies and selection of actual dependencies for the propagation of changes. The authors considered method for restriction of the search space of dependencies into an actual subspace. For this purpose, the authors introduced the concept of engineering object parameter dependent affect zone. Contribution to research in modeling of dependencies by the authors includes two additional methods. They are description of information content of dependencies and introduction of concept of engineering object for description of any physical or logical modeled objects in lifecycle of product. Engineering object is characterized by information content of its attributes as well as inside and outside dependencies.

The paper is organized as follows. After an introduction to the proposed modeling, the authors cite and explain the related research and their own research in related topics. Following this, change affect zone (CAZ) of an engineering object parameter is introduced to define a restricted search space in the graph for consequences of an object change in product model. Next, a comparison is given for better understanding of data and content orientations of product model and modeling. Finally, extension to industrial PLM systems in order to realize the proposed modeling is outlined.

2 Purpose and Preliminaries

Construction of product in model space during product development utilizes high number of modeling software tools for the generation of arbitrary elements, structures, and associative relationships amongst them. Equations, logical relations, rules, checks, and responses are available for the definition of associative relationships. The chance for high level engineering activities is currently decreased by poor representation and processing of associative connections. High number ad-hoc associative connection, pure data descriptions of relationships and poorly structured associative connections constitute main causes of this situation.

Improvement of current advanced product modeling by a new method for organized processing of associative definitions amongst modeled objects is in the focus of this paper. Efficient support for decisions on parameters of engineering objects would require automation of survey of actual associative connections. Because current product modeling cannot provide transparent structure of associative connections this is impossible. Manual tracking of connection chains is time consuming is a source of errors and mistakes. As a consequence, responsible engineers often instruct engineers to define associative objects only within separated units of products.

In the following, several relevant results are discussed in order to placing the reported research in the related research activities. Cited researches are for human activities and model creation (Fig. 1) in information modeling, extraction of views from product information, form feature recognition, knowledge capitalization, definition of associative features, and multi-disciplinary character of work of engineers.

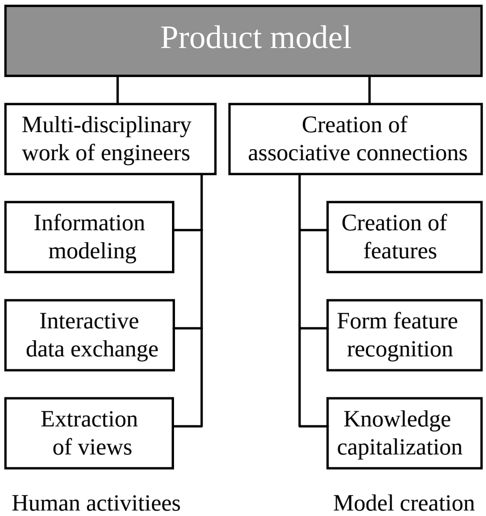

Figure 1
Related research

Information modeling is an important communication between engineering and product modeling. IDEF1-based process-oriented information modeling methodology is proposed in [1]. The IDEF0 process model is integrated with the enhanced IDEF1 information model. The result is easy identification and analysis of information requirements through the corresponding process models. Recent method is extraction of application specific product data subsets from large and very complex product models in the form of views. Views support efficient product modeling. An integrated design framework is shown in [2] where the product model used by the process planner is extracted from the global product model by filtering.

Complex shapes of mechanical parts are constructed in the course of a sequence of shape modifications by form features. When a shape is constructed by different system or shape modification information is unavailable, sequence of shape modification can be reconstructed by feature recognition. In [3], graph based and ‘hint’ based methods, convex hull decomposition, and volume decomposition-recomposition techniques are introduced.

Integration more or less knowledge in product model is one of the evergreen issues. Approach and methodology in this paper are attempts to establish a new direction of research in knowledge-based methods. Numerous recent works show the actuality of research in knowledge based product models. In [4], an approach to definition and mapping of knowledge, based on the point of view of an expert in manufacturing is discussed. The authors of [4] propose tools and models for knowledge capitalization.

Research in associative connections generally focuses onto partial problems of product models and cannot provide general solutions. Paper [5] presents the associative assembly design feature as a new type of features. This new feature allows associations between parts that have not been defined geometrically, between geometric entities defining interfaces between parts, and between part geometry and intermediate geometry used to define a part. Extension to traditional assembly feature properties allows product architectures to be defined using features. Despite process orientation in product data management (PDM) systems, support of flow of product information is weak in current engineering systems. In paper [6], interfacing knowledge oriented tools and CAD application is identified as a technical gap for intelligent product development. The authors of [6] consider definition of associative features in the form of self-contained and well-defined design objects as essential for high-level reasoning and the execution of decisions.

Finally, product modeling requires high level of multi-disciplinary activities with participation by high number of areas of expertise. Paper [7] emphasizes very multi-disciplinary character of work in early stage of the aircraft design. Large variety of specialized tools must be compatible. Otherwise, interface problems are the consequence.

The authors did several projects in topics associated with the subject of this paper. They proposed improvements for industrial modeling in CAD/CAM systems towards more intelligent and human centered engineering processes (Fig. 2). Integration of product data management (PDM) with product modeling is supposed. In order to establish an enhanced human-computer interaction (HCI), they analyzed then modeled human intent [8]. Intent of any person who has influence on decisions of engineers is considered. The knowledge is always corporate accepted one and it is defined, filtered, and accepted according to human intent [9]. Method for associative engineering object definition and product behavior analysis driven management of product changes was published in [10]. As complex model object for closely connected product and other related objects, the authors introduced the concept of integrated model object (IMO) [11]. As a preliminary analysis for the integration of the above methods with the methodology of modeling in CAD/CAM systems, the authors of this paper surveyed problem solving techniques available at model-based engineering [12].

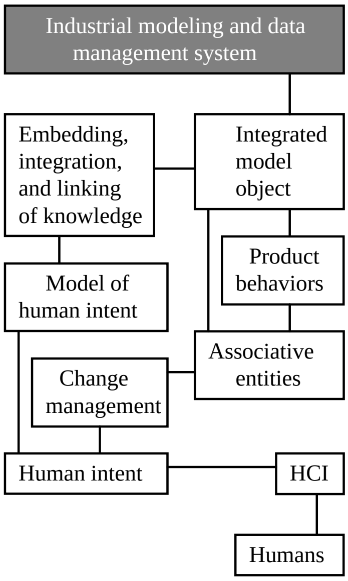

Figure 2
Research by the authors

3 Change Affect Zone in Associative Product Model

Unorganized associative definitions make product models increasingly hard to survey in recent years. In conventional modeling, engineering objects are defined, related with other engineering objects, and their parameters are calculated. Relating is defined amongst parameters of the related engineering objects. However, there is not any description for structure of relationships. In order to fill this gap, the authors proposed description of dependency structure, affect zone for change of an engineering object parameter, and modeling of information content of associative connections as methods for organized description of dependencies of engineering objects in product models (Fig. 3). These methods are considered as ones auxiliary to proven methods in the present practice of product modeling.

Dependency structure can be represented as a graph where nodes are engineering objects represented by the actual parameter or parameter set, and arcs are associative definitions. Change affect zone (CAZ) of an engineering object parameter defines a restricted search space in the graph for consequences of its change. Information content may include any things about origin and intent of an associative definition that is needed by any engineering activity during the lifecycle of a product. Information content depends on task, humans, and environment.

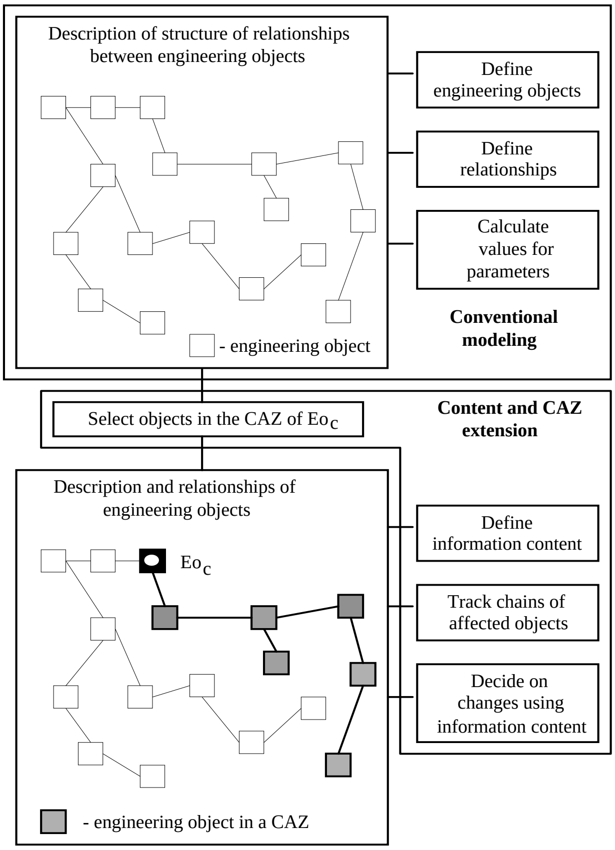

Figure 3
Extended approach to product modeling

Fig. 4 explains role and place of associative connections in a product model. Four essential groups of elements for construction of a product model and their basic associative connections are shown. Elementary product entities are applied as construction elements of parts and are connected as elementary shapes, etc. and by their parameters. Components of products are associative with elementary entities, other components, entities for their analysis, and manufacturing processes. This approach is suitable for both current product modeling and the modeling extension by the authors. Models are defined and modified by knowledge driven and human controlled modeling procedures.

The next step in discussion of the proposed approach is systemics of the proposed extension to product modeling (Fig. 5). As it was stated above, current engineering modeling systems are composed by elements and associative connections in product models and modeling procedures. Extension includes procedures for the definition and processing of human intents, information contents, and associative procedures. Extension to product model includes the following new entities.

- Product object behavior and situation for its definition [11].
- Multiple human intent filtered knowledge for embedding, integration, or linkage [8], [9].
- Change affect zone as it is defined above.
- Structure of associative connections in a purposeful form of graph.
- Adaptive action to carry modification information [10].
- Entities for information content (see next section)

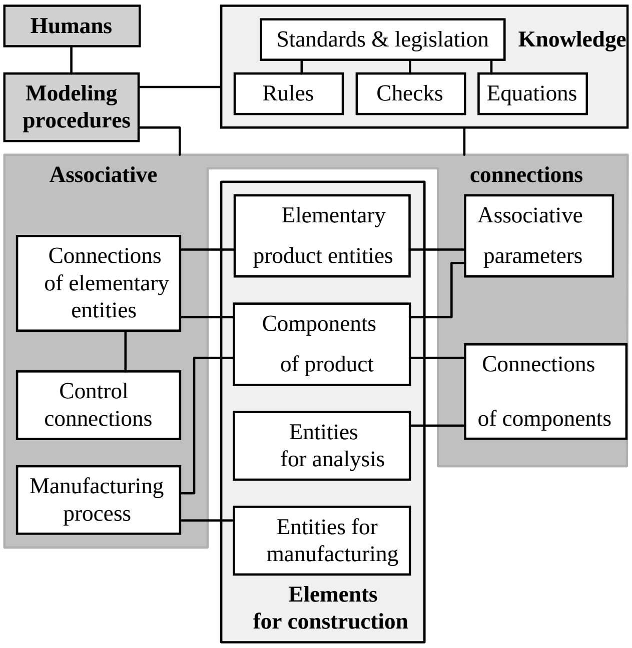

Figure 4
Associative connections in product model

Structure of associative connections requires very flexible and traceable description with a representation of several different states of adaptive actions for the execution of changes along chains of associative engineering objects in affect zones.

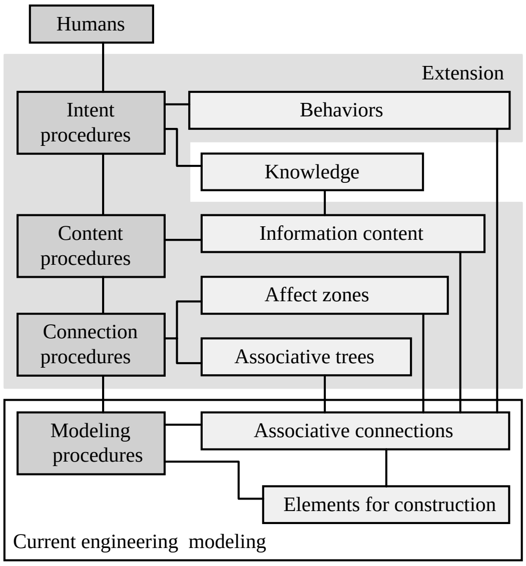

Figure 5
An outline of the proposed extension to product model

A parameter of an engineering object may be modified by different associative connections. At the same time, it can receive different change attempts. Node in the structure of associative connections is an intersection of different change chains for different parameters. At the same time, a parameter may have different connections (Fig. 6). A connection may receive different change attempts in different change chains. Status of a change attempt in a change chain may be 'under revision', 'under discussion', 'argued', 'decided'. Parameter values for product variants and solution alternatives may be also mapped to the node.

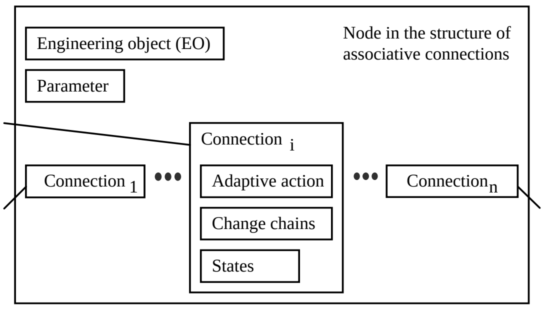

Figure 6
Node in structure of associative connections

4 Information Content in Product Model

In the focus of the proposed modeling is completing data orientation of the current product modeling systems by knowledge representations based information content orientation. One of the related problems is that current knowledge representations in product modeling systems are stored as data, while humans carry content. In order to efficient decision assistance, the authors completed data oriented model by information content oriented model. Information content is arranged in a multi-level schema. Mapping of information content representations also requires multilevel structure of data representations. Although conventional data oriented modeling uses multilevel structures for partial models such as form feature information model in the STEP standard for product modeling [13], a new overall approach to leveling was necessary to develop.

A comparison in Figs. 7 and 8 serves better understanding of data and content orientation of model and modeling. The authors analyzed data oriented product models. They recognized that product model contains description of engineering objects by their attributes, relationships of attributes, and history of model construction (Fig. 7). Elements and units in model descriptions are defined for engineering objects. Definition of engineering objects and construction of product model are supported by engineering object and structural information specific modeling procedures. The proposed multilevel structure of the data oriented product model is also shown in Fig. 7. Identification of engineering object points to application data mainly for the purpose of specification of essential design information. Detailed description of an engineering object is preceded by definition of its associative connections with other engineering objects. Engineering object is described by its attributes. Representations are mapped to attributes.

As it is stated above, information content of the product objects and the related other engineering objects is not described in data oriented models. As a contribution to a possible solution for this problem, the following main characteristics of the proposed content oriented product models were decided as objectives.

- Content information must assist effective communication between engineers and data oriented modeling procedures.
- Content information enough for explanation and evaluation of modeled objects and their environment must be represented in product model for modeling tasks.
- Content information must be enough for saving compliance of product model data with intent of responsible engineers.
- Knowledge from all relevant sources must be defined and involved as information content by the integration of knowledge.
- Content information is an extension to data oriented description and it is associative with data descriptions.

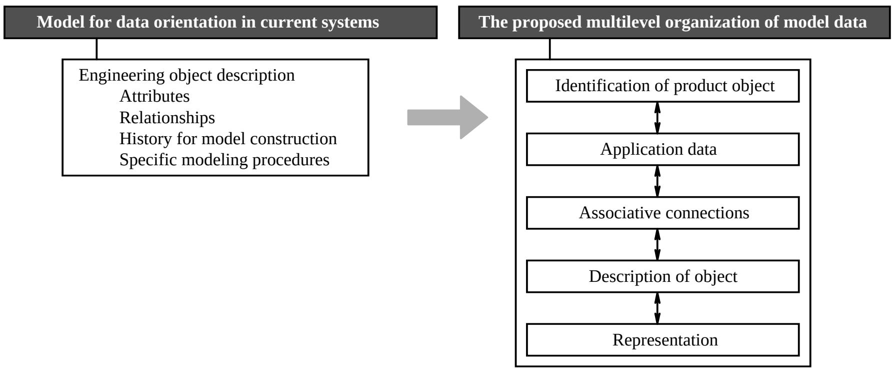

Figure 7
Unstructured and structured data oriented product model

Multilevel structure of the content oriented product model is shown in Fig. 8. Because an extension of current data oriented product model is aimed, multilevel organization of data oriented model (Fig. 7) is applied as an interface between the conventional data oriented and the information content oriented sectors of a product model. Engineering activities are initiated by definitions of human intent and are aimed at making decisions on product model objects (Fig. 8). Making, revising, and reproduction of interrelated decisions on engineering objects need information about meanings of concepts and contexts of the decided items, and engineering objectives.

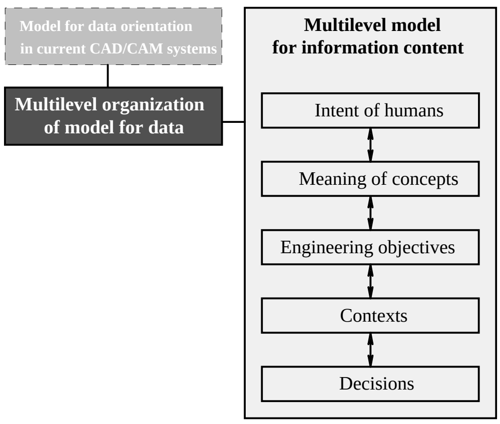

Figure 8
Content oriented product model

5 Modeling in PLM Systems

Extension to industrial PLM systems in order to realize the proposed modeling relies upon rich software for the development of CAD/CAM and CAE systems in application environments (Fig. 9). Other functional units of PLM systems are for management of product data in case of different modeling systems, interoperability to enable data exchange with non-integrated modeling systems, as well as group work and Internet portal communication. Modeling procedures, model data structures and the graphic user interface can be accessed from outside programs in the extension developed by using of tools that are available in PLM systems. Access is through standard application programming interface (API).

The above outlined environment is under continuous development as an experimental system at the Laboratory of Intelligent Engineering Systems (LIES) of the Institute of Intelligent Engineering Systems, John von Neumann Faculty of Informatics, Budapest Tech. Recently, LIES has been equipped with leading industrial PLM, intelligent computing, and mathematics software, among others for the purpose of experiments with information content oriented modeling. Research work in information content modeling will concentrate on better understanding of content model entities and their interconnections with data oriented modeling in the next future. The main issues are coexistence and relationships of content and data oriented model entities. Typical content entities will be defined in accordance with proven product model data representations.

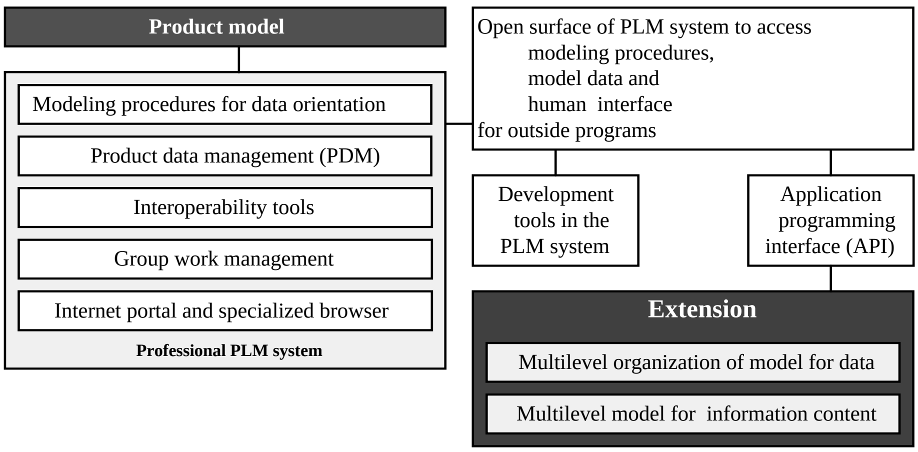

Figure 9
The proposed modeling in a PLM system

Conclusions

The paper highlighted the problem of dependencies and proposed a new modeling method in order to compete the present practice by a new information content based model description. This method is devoted to assist humans at their decisions on engineering objects during product development in virtual environments. This work is motivate by a situation in which decision assistance would require representation of much more information about dependencies for calculation of parameters of modeled objects and evaluation of consequences of changed values of those parameters than it is possible in recent industrial modeling systems.

Change affect zone (CAZ) has been defined for engineering object parameters. CAZ defines a restricted search space in the graph of consequences of a change. Information content based product model entities are defined to be capable of description of any things about origin and intent for associative definitions. Information content depends on task, humans, and environment.

As for the development of the extension of a PLM system for the proposed modeling, modeling procedures, model data structures, and graphic user interface elements can be accessed and defined by using of special software development tools that are available in PLM systems.

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References

[1] P-H. Chen, C. Wana, R. L. K. Tionga, S. K. Tinga, Q. Yangb, “Augmented IDEF1-based Process-oriented Information Modeling,” in *Automation in Construction*, Vol. 13, Issue 6, November 2004, pp. 735-750

[2] H. Paris, D. Brissaud, “Modeling for Process Planning: the Links between Process Planning Entities,” *Robotics and Computer-integrated Manufacturing*, Volume 16, Issue 4, August 2000, pp. 259-266

[3] J. J. Shah, D. Anderson, Y. S. Kim, S. Joshi “A Discourse on Geometric Feature Recognition From CAD Models,” in *Journal of Computing and Information Science in Engineering* Journal of Computing and Information Science in Engineering -- Volume 1, Issue 1, March 2001, pp. 41-51

[4] J. Renaud, “Improvement of the Design Process through Knowledge Capitalization: an Approach by Know-how Mapping,” in *Concurrent Engineering*, Vol. 12, No. 1, 25-37 (2004)

[5] Y.-S. Ma, G. A. Britton, S. B. Tor, L. Y. Jin, “Associative Assembly Design Features: Concept, Implementation and Application,” in *The International Journal of Advanced Manufacturing Technology*, Volume 32, Numbers 5-6 / March, 2007, pp. 434-444

[6] Y.-S. Ma, T. Tong, "Associative feature modeling for concurrent engineering integration,” in *Computers in Industry*, Volume 51, Issue 1, (May 2003), pp. 51-71

[7] C. Ledermanna, C. Hanskeb, J. Wenzelc, P. Ermannia, R. Kelm, “Associative Parametric CAE Methods in the Aircraft Pre-Design,”*Aerospace Science and Technology*, Volume 9, Issue 7, October 2005, pp. 641-651

[8] L. Horváth, I. J. Rudas, “Human Intent Description in Environment Adaptive Product Model Objects,” in *Journal of Advanced Computational Intelligence and Intelligent Informatics*, Tokyo, Vol. 9, No. 4, pp. 415-422, 2005

[9] L. Horváth, I. J. Rudas, C. Couto, "Integrationration of Human Intent Model Descriptions in Product Models", in *Digital Enterprise - New Challenges Life-Cycle Approach in Management and Production*,: Kluwer Academic Publishers, 2001, pp. 1-12

[10] L. Horváth, I. J. Rudas, J. F. Bitó, G. Hancke, “Intelligent Computing for the Management of Changes in Industrial Engineering Modeling Processes,” in *Computing and Informatics*, Vol. 24, 2005, 1001-1013

[11] I. J. Rudas, L. Horváth, “Process Oriented Engineering Using Highly Integrated Adaptive Computer Descriptions,” in proc. of the *32th Annual Conference of the IEEE Industrial Electronics Society, IECON 2006***,** Paris, France, 2006, pp. 3568-3573

[12] L. Horváth, I. J. Rudas, “*Modeling and Problem Solving Methods for Engineers* “, ISBN 0-12-602250-X, Elsevier, Academic Press, 2004, p. 330

[13] Ricardo Jardim-Goncalves, Nicolas Figay, Adolfo Steiger-Garcao, “Enabling Interoperability of STEP Application Protocols at Meta-Data and Knowledge Level,” *International Journal of Technology Management*, Volume 36, Number 4, pp. 402-421, 2006