

Adaptive Object Definition in Lifecycle Engineering of Products

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***Abstract:** This paper introduces a new method for the representation of knowledge that improves communication between engineer and object generation processes in the definition of product objects in modeling systems. New knowledge representations are introduced to improve knowledge representation capabilities of current product modeling systems to allow better understanding of product model, coordination of change requests, and establishing a new adaptive product definition. Analysis of current product model definition process is followed by comparative introduction of the proposed new knowledge definition and processing. The method called as personal intent based product object definition is one of the results of a long term research activity by the authors in the topic group of human controlled automation of engineering activities in product lifecycle management (PLM) systems.*

***Keywords:** product lifecycle management; product model; knowledge based product definition; decision in engineering.*

1 Introduction

Activities of engineers depend on communication of knowledge. In the old times, knowledge is discussed and communicated on written documents. Recently, the new medium of product model together with object orientated procedures is increasingly capable of communication, representation, and store of knowledge accessible by model handling processes and authorized humans (Fig. 1).

Communications in product lifecycle management (PLM) systems are sketched in Fig. 1. Knowledge sources are available for engineers and other authorized people in order to support their decisions on product objects. These decisions by individuals must be coordinated with other persons or simply passed to an acceptance process according to company measures, etc. This is why engineers communicate intended product information with product model definition and access procedures. Product data management functionality handles engineering

processes and product model. Product model serves as medium to carry organized product information. Increasingly important communication is realized as information exchange with equipment control, and measuring and capturing devices. PLM implies lifecycle management of product information including recycling.

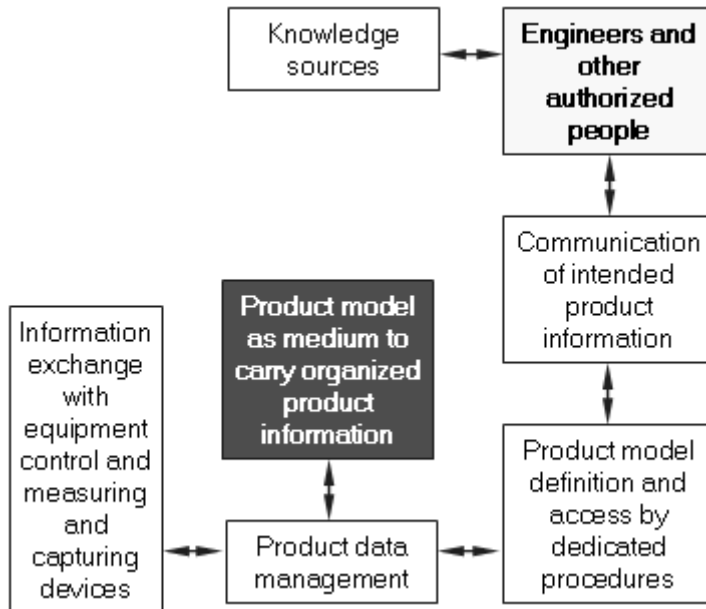


Figure 1. Communications in PLM systems

Group work activities of engineers gained increasingly sophisticated and integrated functionality in PLM systems. Engineers are organized in groups and product model serves increasingly as the only communication medium within a group. Other media can be involved only with highly decreased efficiency of the expensive modeling environment. Because current product models can not serve as the only medium in the communication within group of engineers, one of the main development areas in engineering is improving the problematic model representation capabilities. The authors of this paper joined to this work and prepared new knowledge based model representations for the communication of engineers. They proposed new model representations for human intent and product behavior [1]. One of their earlier works analyzed possibilities for the integration of objects in product model in order to achieve simple and transparent structures for decisions [2]. Their work in content based object definition is the most relevant to this paper [3]. They organized basic methods for product model based engineering problem solving in [4].

Recent sophisticated environments in virtual engineering systems are developed towards complete spaces where product and its environment can be represented in order to produce the same behaviors as in the reality after production. Because increased proportion of prototyping is done in virtual, organized product element analyses are called as virtual prototyping [5].

Virtual systems need advanced modeling for wide application in various areas of engineering. Standard STEP (Standard for the Exchange of Product Model Data, ISO 10303) of product model by the International Organization for Standardization first covered integrated model for all engineering activities. It relies upon generic and application resources as well as application protocols [6]. Product lifecycle management (PLM) is considered by the author of the book [7] as a new paradigm to manage products all the way across their lifecycles in the most effective way.

Representation of knowledge in product model is also a developing area without real breakthrough. Numerous causes led to slow development of integrated and acceptable knowledge representations in product model. Perhaps the main cause is responsibility. Other problem is that the same decision may depend on various intents, experiences, and opinions. Company, project, application area, and responsible human specific characteristics of knowledge cause major difficulties even considering the recent advanced knowledge technology [8], [9].

The results in this paper were selected to introduce in the form of oral talk on the ICETET 2011, the 4th International Conference on Emerging trends in Engineering & Technology, Mauritius, 2011 November [10]. This annual conference is an event in the conference program of IEEE with worldwide participation of internationally recognized researchers.

In this paper, analysis of current product model definition process is followed by comparative introduction of the proposed new knowledge definition and processing. The method called as personal intent based product object definition is one of the results of a long term research activity by the authors in the topic group of human controlled automation of engineering activities in product lifecycle management (PLM) systems.

2 Current Product Definition Method

Well proven industrial technology for lifecycle modeling of products is well suitable for engineering activities in wide range of applications and engineering areas. This technology includes typical product object definition as it is outlined in Fig. 2. Human makes decision on product objects according to authorization based on role in a work group. Decisions of this human are restricted by outside demands and specifications. Most important outside demands came from

threshold knowledge, higher level decisions including law and standards, and quality assurance.

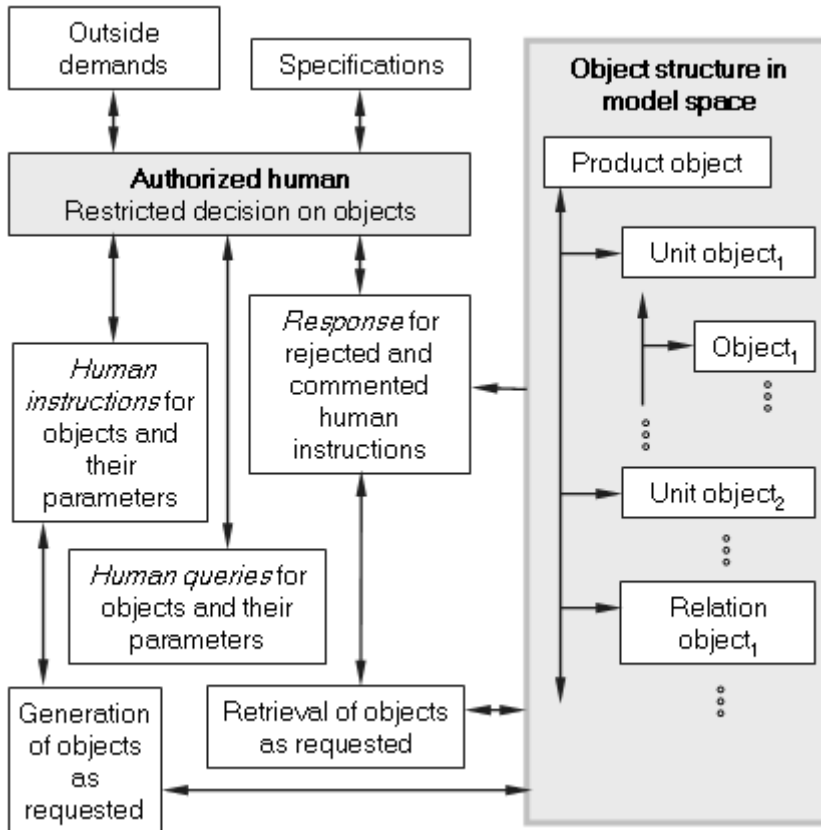


Figure 2. Product definition at modeling

Human places instructions for objects and their parameters in a dialog with procedures for the generation of object representations in the relevant product model. Generation of objects is done as requested by the human. However, procedures consider contextual connections, threshold knowledge, and other restrictions and response when human instructions rejected and commented because of breaking some of the restrictions. At the same time, the same human places queries for objects and their parameters existing in the product model. Product model includes entities for object representations in a structure as it is illustrated in Fig.2.

3 Knowledge for Intended Modification of Product

The challenge of knowledge representation suitable both for modeling theory and methodology and for the industrial experience and expertise in a well defined product class and production company requires human defined knowledge in product model. Different humans define different knowledge. Generally, any of them is valuable at given circumstance. Because circumstances are changed frequently during product development, the best solution is storing alternatives in product model.

During product object definition, authorized human applies knowledge in the

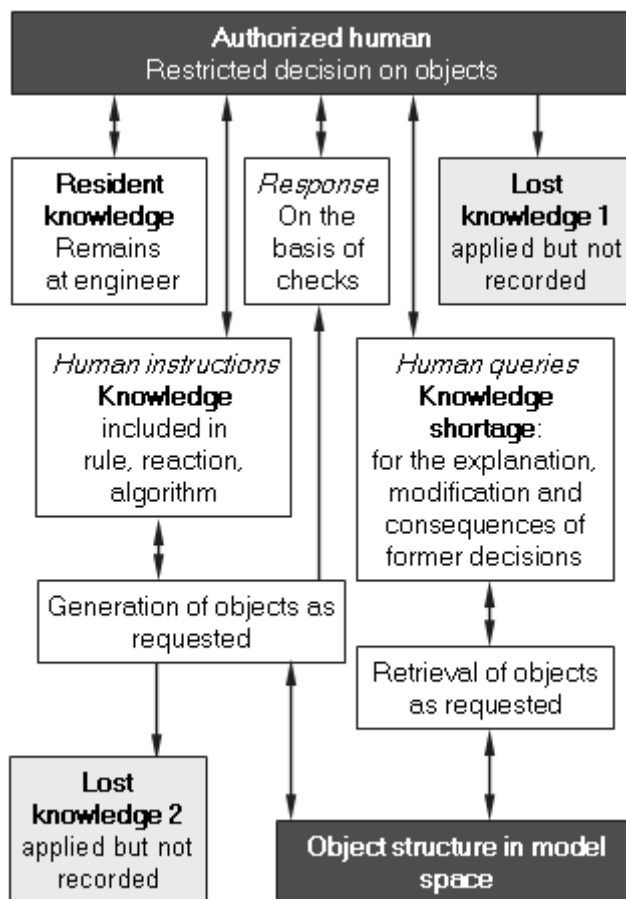


Figure 3. Knowledge utilization in currently applied product modeling

course of restricted decision on product objects. However, restricted knowledge representation capabilities of current product modeling systems do not allow for representation of the knowledge necessary for understanding intent of human.

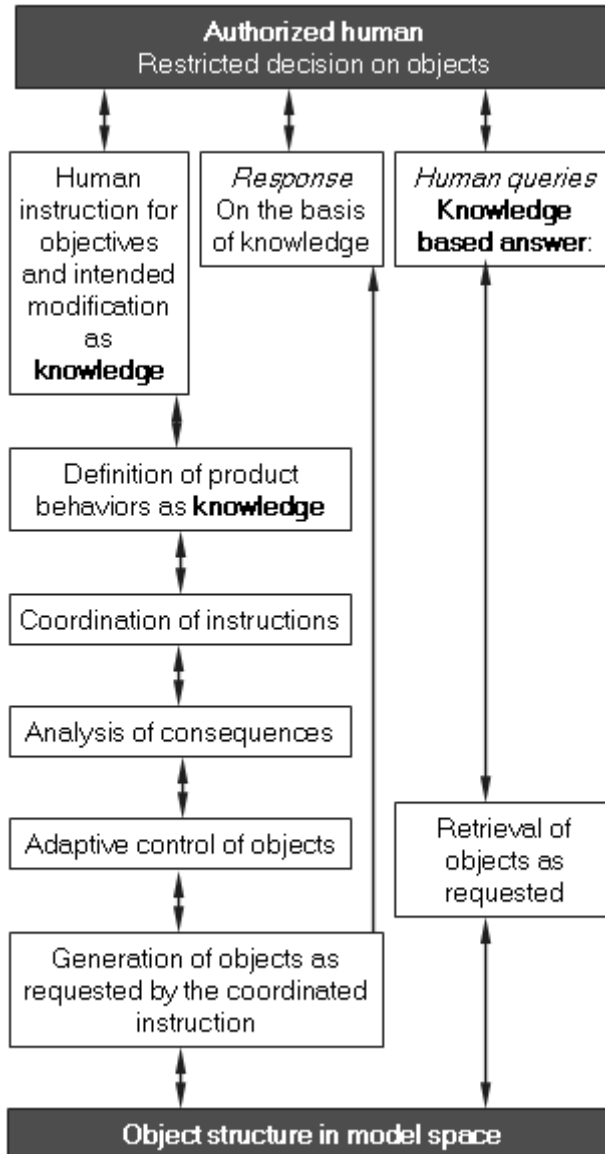


Figure 4. Knowledge utilization in the proposed product modeling

Most of knowledge remains at the human as resident knowledge and some knowledge gets lost (Fig. 3). At the same time, current advanced modeling systems offer simple, efficient, and engineer understandable knowledge in the form of rule, check, reaction, and algorithm.

Checks are applied to recognize situations and response for human instructions. At the generation of objects, these knowledge representations are active. Some of the knowledge that is communicated with object generation processes is applied but not recorded. At human queries, only the represented knowledge can be retrieved. Knowledge shortage causes unanswered questions in explanation, modification, and consequences of former decisions.

In order to decrease the knowledge shortage at the communication of engineers in group work and establish a new contribution to an enhanced modeling for this purpose, the authors of this paper proposed the background knowledge assisted product modeling process. The main difference between the currently prevailing (Fig. 3) and the proposed (Fig. 4) methods is that human is not allowed to communicate the pure result of thinking process with the model generation processes as unexplained object parameters. Instead, knowledge is communicated for the purpose of the above communication. Other benefit is that this knowledge assures repeated object parameter generation if necessary by the coordination of instructions from different humans and analysis of consequences. Knowledge can also represent possible modification of parameters for various situations. The other difference is that object generation is product behavior driven. Behavior represents function and quality. Direct human instruction of object generation processes is replaced by knowledge based decision driven adaptive control.

In the proposed method, response of modeling system is part of the above knowledge based decision process. All knowledge is advised to include in this background knowledge assisted product modeling process. Although, direct response from the object generation processes is still working.

4 Process for Personal Intent-based Object Definition

Human influence in a successful product modeling is based on argue and tradeoff considering any eligible opinion, intent, or decision by individuals. Sometimes, product object definition is done by a single engineer. In this case, it is advised to involve outside consultant in the decision. In the method proposed by the authors, this consultant is included in the product model as one of the influencing humans.

The proposed background knowledge assisted product modeling process is an engineering process and consists of component modeling processes. Most important component processes include human thinking and communication

process, process for the definition of behaviors, and process for the propagation of intended influences.

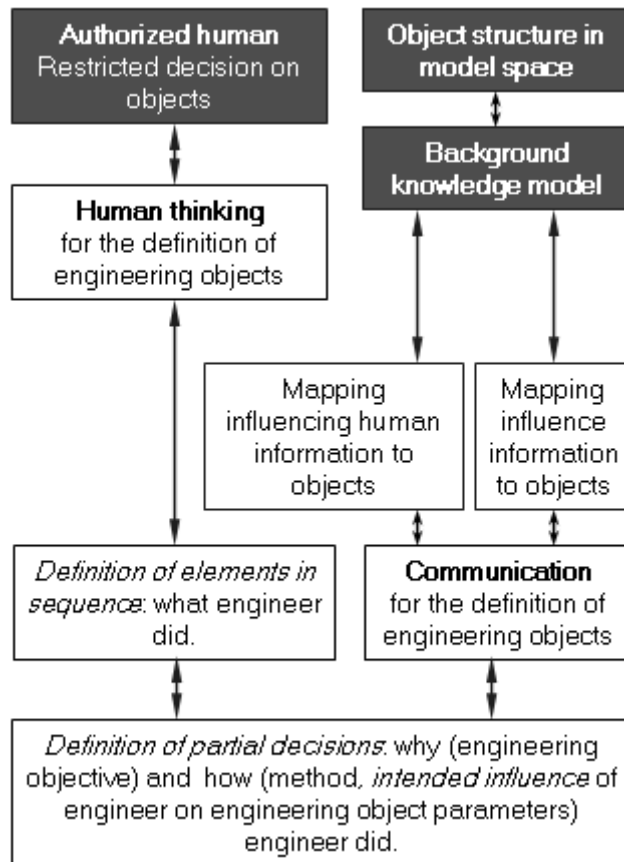


Figure 5. Object definition by human

Engineering process and its component modeling processes represent global level of product modeling while the current object generation purposed elementary modeling processes represent local level of product modeling. Coordinated decisions are made on global level then global level results drive local level object generation. This approach by the authors of this paper makes it possible to establish a new global level as an extension of the current local level product modeling.

Human thinking and communication process generates influencing human and influence related information and maps it to objects (Fig. 5). Object representations are handled on the local level as it is explained above. Results of

human thinking for the definition of engineering objects is knowledge based instruction including definition of elements in sequence representing what engineer did and definition of partial decisions representing why and how engineer did. This instruction is considered as an influencing attempt and includes engineering objectives as answer the question why, and method based intended influence as answer the question how human defined object parameters. The resulted influencing human and influence information are placed in the background knowledge model in relation with the object structure in model space.

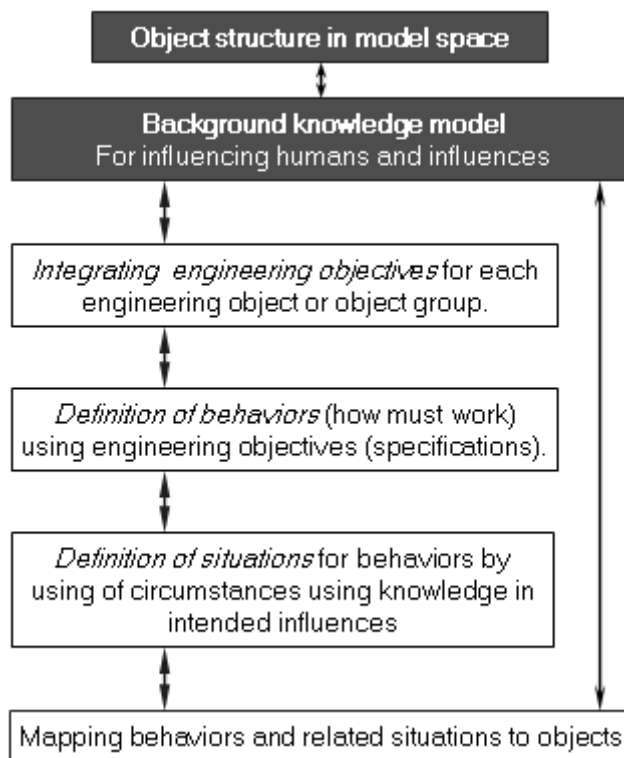


Figure 6. Definition of product behaviors

Process for the definition of behaviors includes integration of engineering objectives for each object or object group, definition of behaviors using engineering objectives, and definition of situations for behaviors by using of circumstances using knowledge represented in intended influences (Fig. 6). Behavior, representing function and quality of a part or unit, tells the human at application of the product model that how product must work. The specifications for this purpose are contained by the engineering objectives. Behaviors and related

situations are mapped to objects in structure and placed in the background knowledge model.

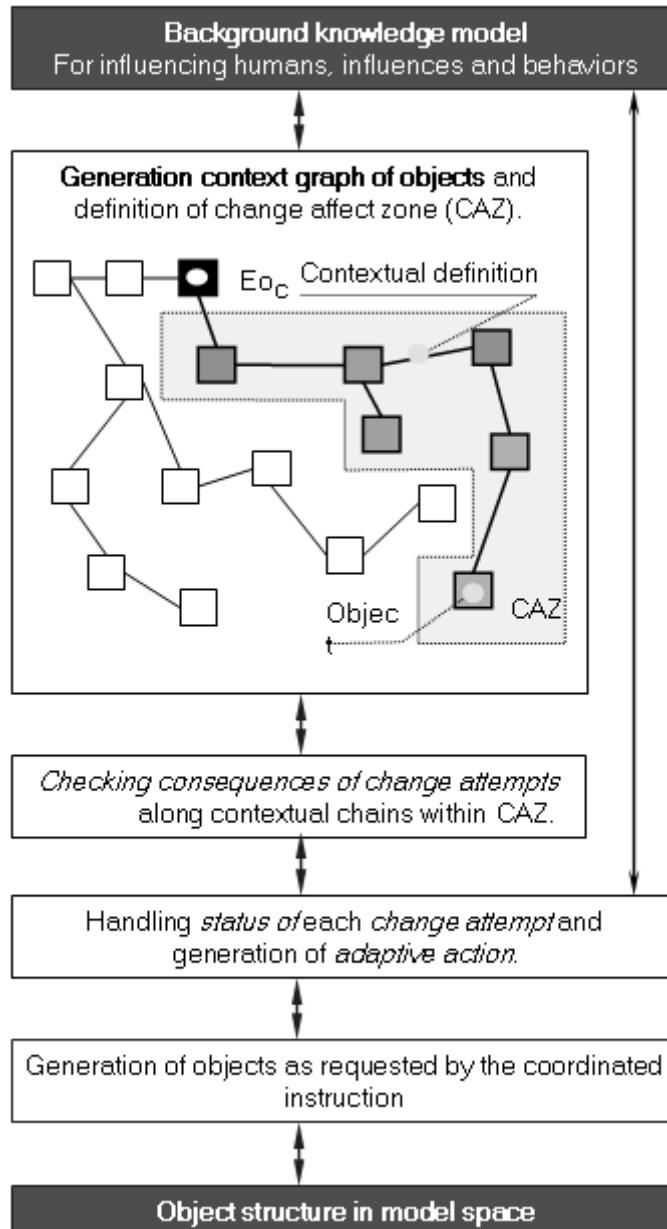


Figure 7. Analysis for consequences

Intended influence is recoded and together with other influences handled as attempt. Coordination of attempts, considering consequence change requests results the final generated or agreed influence in adaptive action. Adaptive action represents executable influence that instructs engineering object generation processes on the local level of product modeling. Execution is allowed by “executable” status of adaptive action.

Consequence changes are revealed by process for the propagation of intended influences (Fig. 7). For this process, influencing humans, influences and behaviors are available in the background knowledge model. Tracking of consequence changes for an intended influence is served by a graph in which nodes represent objects and edges represent contextual connections defined for pairs of objects. Contextual chain is generated using contextual connections. Contextual chains for an intended influence constitute change affect zone (CAZ) within which objects have chance for change as a consequence of the intended influence. In the course of coordinated checking of change attempt consequences, status of each intended influence and the related adaptive action are handled. Objects are generated as requested by the coordinated instruction in adaptive action.

5 Knowledge Represented Intended Influence

In the proposed method, a new knowledge control for engineering objects communicates intended influence from engineer to knowledge based product object handling processes. Definition of intended influence (Fig.8) is a critical element of the proposed method because, in case of its acceptance, any relevant object parameter calculation for situations is done according to the included knowledge. Intended influence can be accepted only as the included knowledge allows. In this way, different intended influences may be set to the same result.

Human who defines objects serves as source of intended influence and has status that may be the same as in case of group work or other states can be applied according to the task or engineering environment. Status may be, for example, authority, approver, analyst, and designer. Human applies knowledge from different sources such as product models, own or company experience, linked materials, and individuals.

Characteristics of influence are status and purpose. Status defines strength and informs about its type. It may be, for example, standard, proposal, decision, opinion, and experience. Type highly determines the consideration of influence because a weak opinion even intuition may determine critical features of a product. Purpose such as strategy, alternative, allowable range of a parameter, also determines the consideration. These characteristics define content and they are not pure administrative information.

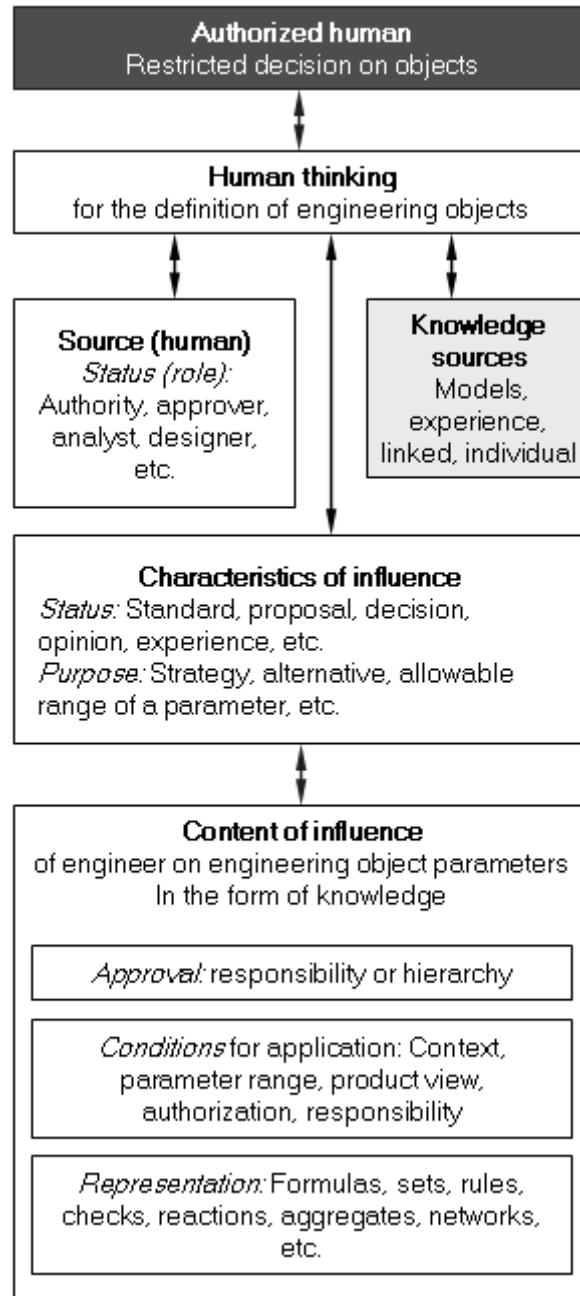


Figure 8. Content of influence on engineering objects

As it was stated above, content of influence on engineering object parameters is represented in some form of knowledge. Knowledge must be approved on responsibility or hierarchy basis. Knowledge may have conditions for application such as context, parameter range, product view, authorization, and responsibility. Main engineer friendly representations are formulas, sets, rules, checks, reactions, aggregates, networks, etc.

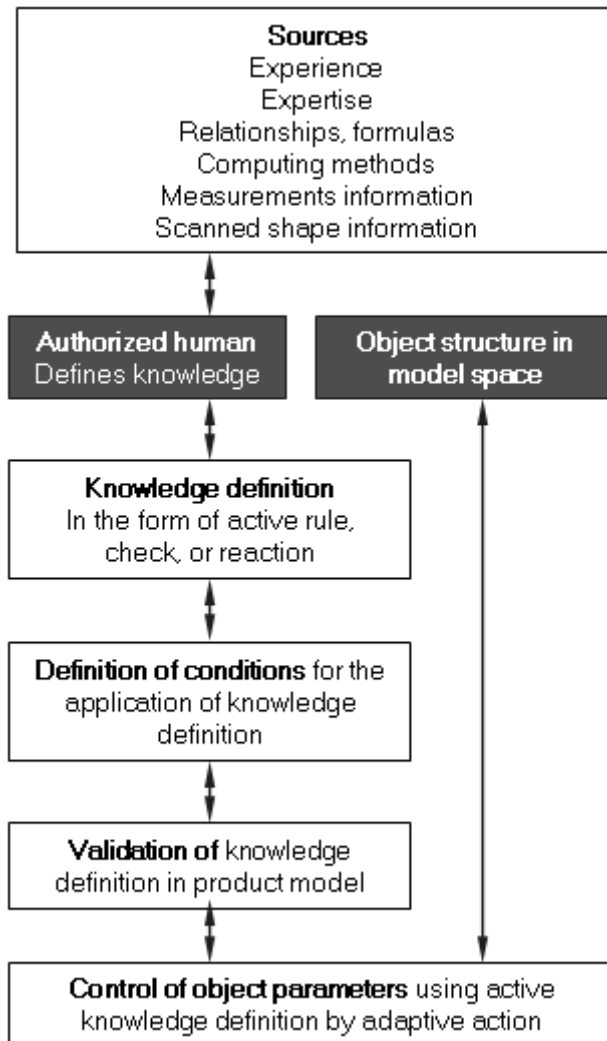


Figure 9. The knowledge process

Fig. 9 shows that how knowledge is defined for an intended influence. Authorized human defines knowledge by using of various sources such as experience, expertise, relationships, formulas, computing methods, measurements information, and scanned shape information. In order to easy build in adaptive action, active knowledge is applied. This is an emerging knowledge application mode in recent product modeling systems. When knowledge entity or any parameter value in it changes, the object parameters calculated by this knowledge change accordingly. Active rule, check, or reaction entities are easy to define by engineers. Active knowledge is waiting for execution in adaptive action. In the meantime, it and parameter values in it may be changed many times without any affect on engineering objects.

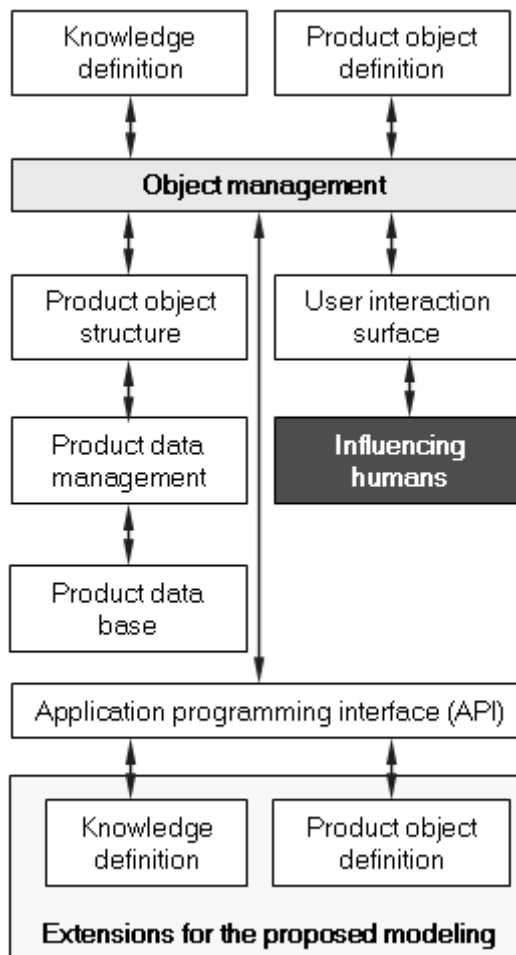


Figure 10. Implementation in object oriented environment

Conditions for the application of knowledge are defined on the basis of experience or calculation. Knowledge is validated by simulation preferably based on field tests. Human who provides enough evidence for influence or receives enough trust to accept a given knowledge entity has full responsibility except for decisions at higher level of hierarchy.

6 Implementation of the Proposed Modeling

The object oriented environment and the application programming interface (API) for its development in application environments makes implementation of the proposed method easier in a well-equipped PLM system. The scenario is outlined in Fig. 10. Object management integrates object definitions such as knowledge definition and product object definition. Product object structure is developed by object definition while object definition is initiated by influencing humans through user interaction surface. Product data management handles product data base. Application programming interface (API) facilitates knowledge definition and product object definition from outside of a PLM system in extensions for the proposed modeling.

Conclusions and Future Research

As part of research in knowledge intensive product object definition, this paper introduces some model representation and model definition process related aspects of the method called as personal intent based object definition. Human defined knowledge in product model must be suitable for modeling theory and methodology and also for the industrial experience and expertise. In the proposed method, influencing human and influence information is placed in the background knowledge model as knowledge represented intended influence. Knowledge for intended modification of product determines product behavior and method for the definition of engineering objects.

Human influence in a successful product modeling is based on argue and tradeoff considering any eligible opinion, intent, or decision by individuals. The main difference between the currently applied and the proposed methods is that human is not allowed to communicate the pure result of thinking process with the model generation processes as unexplained object parameters. Instead, knowledge is communicated for the purpose of the above communication.

Future research must be conducted to answer the question that how model entity is to be defined and how the related modeling procedures should work for a practice allowable product definition. Prototypes of new product and process model entities should be analyzed for placing them between the human and the current model generation processes.

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References

- [1] L. Horváth, "New Design Objective and Human Intent Based Management of Changes for Product Modeling," in *Acta Polytechnica Hungarica*, ISSN 1785-8860, Budapest, Hungary, Volume 4, No. 1, 2007, pp. 17-30
- [2] L. Horváth, I. J. Rudas, Human Intent Description in Environment Adaptive Product Model Objects, *Journal of Advanced Computational Intelligence and Intelligent Informatics*, Tokyo, 9(4), 415-422, (2005)
- [3] L. Horváth, Imre J. Rudas, "Engineering Objective Driven Product Lifecycle Management with Enhanced Human Control," In book *Towards Intelligent Engineering and Information Technology*, in Series: *Studies in Computational Intelligence*, Vol. 243, Springer-Verlag, Berlin, Heidelberg, 2009, pp. 543-556
- [4] L. Horváth, I. J. Rudas, *Modeling and Problem Solving Methods for Engineers*, Elsevier, Academic Press, New York, etc., 2004, p. 330
- [5] S. H. Choi and H. H. Cheunga, "A versatile virtual prototyping system for rapid product development," *Computers in Industry*, Vol. 59, No. 5, pp.477-488, (2008)
- [6] R. Jardim-Goncalves, N. Figay and A. Steiger-Garcia, "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)
- [7] J. Stark, *Product Lifecycle Management: 21st Century Paradigm for Product Realisation*, Birkhäuser, 2004, p. 441
- [8] G. Colomboa, A. Mosca, and F. Sartori, "Towards the design of intelligent CAD systems: An ontological approach," *Advanced Engineering Informatics*, Vol. 21, No. 2, pp. 153-168 (2007)
- [9] Preece, A., Flett, A., Sleeman, D., Curry, D, Meany, N., and Perry, P., "Better knowledge management through knowledge engineering," *Intelligent Systems*, IEEE, Vol. 16 No. 1, pp. 36-43 (2005)
- [10] L. Horváth and I. J. Rudas, "A New Adaptive Process for Product Model Object Definition," in *proc of the ICETET 2011, the 4th International Conference on Emerging trends in Engineering & Technology*, Mauritius, 2011, in press