New and Classical Definitions for Products in PLM Models

László Horváth, Imre J. Rudas

Budapest Tech, Bécsi út 96/B, H-1034 Budapest, Hungary
horvath.laszlo@nik.bmf.hu, rudas@bmf.hu

Abstract: Engineering processes are defineed by modeling representing human intent at the decisions on strongly interrelated engineering objects. Engineering objects are not only objects in the product structure but also include objects for analysis, manufacturing, production, etc. Current product modeling systems apply well-proven information based modeling and model for product related engineering activities in the industry. The authors analyzed this classical form of modeling and developed a methodology to improve communication between engineer and information based modeling procedures. The proposed methodology is also aimed to enhance indirect communication between engineers by using of the product model as a medium. In this paper, thinking process of human for product definition, information content based modeling, changed application of knowledge, and restricted automation of engineering decision processes are discussed. A comparison of information and information content based product modeling methods are given. In addition to enhanced human-computer and human-human communication, higher level of automation in product related engineering mainly in decision making is also aimed.

Keywords: Product modeling, human-computer interaction, decision assistance, information content based model

1 Introduction

Product models are organized in central data bases under the management of product data manager systems. Product lifecycle management systems organize information and processes for lifecycle product engineering. In a high level integration of engineering, activities are organized around portals. While this new style of engineering brought solution for high number of problems, several new problems were emerged. This paper analyzes some of them and reports efforts by the authors to produce solutions.

Product development is characterized by high number of concurrent and strongly interrelated decisions. While product models record huge amount of information for decision making, the new style of engineering leaves little chance for direct consultation between engineers at re-evaluation, extension, and revision of earlier decisions for changed circumstances. Consequently, indirect communication through product model is to be improved. For this purpose, information content of product model should be enriched by some elements from human thinking process in some form of knowledge. However, classical definitions of knowledge must be reevaluated in order to fitting it to specifics of product modeling. The most important of these specifics is that influence of more or less humans must be considered at a decision.

The above train of thought has led the authors to consider product definition as a process where humans define product information by using of content of information in product model. In order to achieve this, new entities are necessary to be defined in the product model for the representation of human intent, engineering objectives, and contextual connections of engineering objects. Processes for definition and change of product information communicate changes of engineering objects with model data creation procedures by changing the above listed new model entities. The new entities initiate changes of product information.

The authors did several research projects and publications that they consider as preliminaries of this research. They analyzed modeling methods and models in order to reveal functions, relationships, and human – computer interactivity in current product modeling practice [8]. Modeling of human intent was researched in close connection with grouping of model entities according to associative connections in environment adaptive product model objects [9]. Additional issue for information content based modeling is modeling of products behaviors. An organized description of engineering object behavior definitions is proposed in [10]. Management of product model changes [11] and its human intent and knowledge management aspects [12] were also important research issues.

In this paper, thinking process of human for product definition, information content based modeling, changed application of knowledge, and restricted automation of engineering decision processes are discussed. A comparison of information and information content based product modeling methods are given. In addition to enhanced human-computer and human-human communication, higher level of automation in product related engineering mainly in decision making is also aimed.

2 The Concept of Influencing Space

Influencing on a product model has been introduced and defined (Fig. 1) by the introduction of influencing space. Influencing space describes all influencing effects on engineering objects and their connections. In the center of an influencing space is a group of humans for a well-defined product development. In this context, product model space is considered as classical one where engineering objects (EO_1-EO_n) are described and related by relationship definitions (R_1-R_m).

A human may act directly or indirectly on engineering objects. Direct acting humans add their influence to the group of engineers using a communication surface. Management an engineer group coordinates work of direct acting humans, controls definitions for organized influences, and is controlled by an extended company [10]. Indirect acting humans control customizing for organized influences and advise extended company at its control over group of engineers. Organized influences control information in product model. Customizing is generalized to all direct and indirect customer affects including national and international standards, and law.

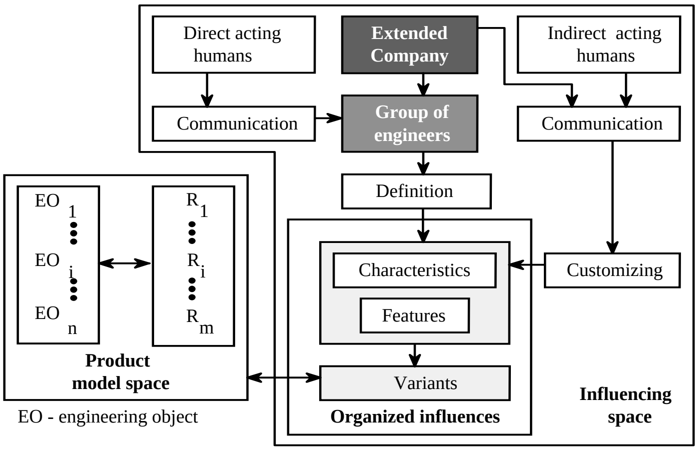

Figure 1
Influencing and model spaces

3 Knowledge Based Issues

Current knowledge based problem solving procedures disregard human related factors such as source of the knowledge, close connection of knowledge with humans, and need for verification of knowledge by responsible humans. Recently, efforts are experienced in this direction. Some of the relevant results are summarized below.

Authors of [1] emphasize the personal and organizational nature of knowledge and propose method for handling. In [2], personalization and codification are shown in the development of a multidisciplinary framework. The authors of [3] propose tools and models for knowledge capitalization. An approach to definition and mapping of knowledge, based on the point of view of an expert in manufacturing is discussed. One of the classical problems is to acquire high quality expert knowledge for product model. Moreover, at most of traditional methods it is assumed that knowledge comes from a single expert. In [4], multiple expert sources are proposed. This approach is considered as a more feasible alternative. Research that is reported in [5], introduces the product lifecycle aspect and the feature principle in a new distributed database and knowledge base modeling approach for concurrent design. The knowledge for product modeling is described by collections of rules in rule-bases. It is applied widely in product modeling. Databases and knowledge bases are placed at different locations for modeling according to different life-cycle aspects of the same product. In paper [6], interfacing knowledge oriented tools and computer aided design 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.

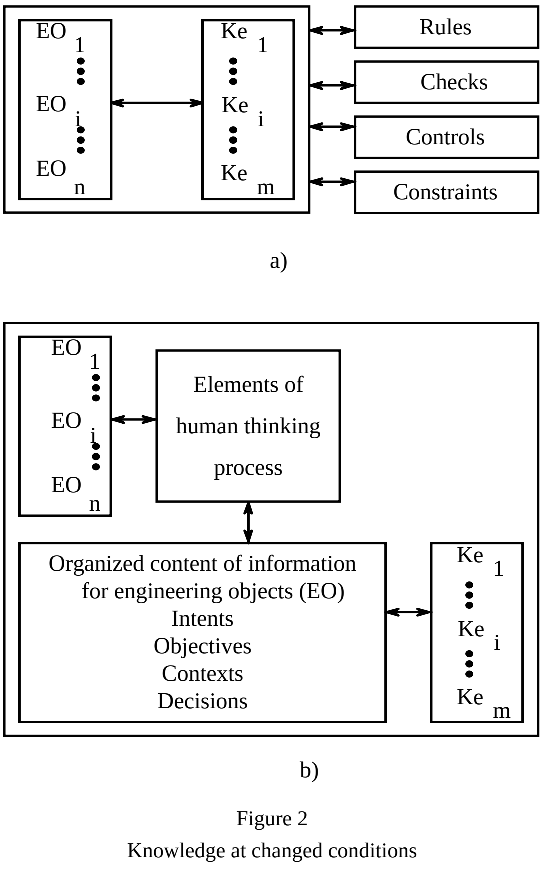

Figure 2
Knowledge at changed conditions

It was recognized that a changed role of knowledge must be defined and a higher level and content driven organization of knowledge is necessary (Fig. 2). In the present product modeling, unstructured information based knowledge entities (Ke) are defined for engineering objects as relationships among them (Fig. 2/a). The changed role of knowledge in the approach by the authors is illustrated in Fig. 2/b. Knowledge is not mapped directly to description of engineering object information. Instead, it is mapped to organized content of information for engineering objects. Content is related to elements of human thinking process and is applied to define information for engineering objects.

A restricted solution space is defined during human decision process. Related thinking process of a human is interdependent with thinking process of other humans in solution of the same problem or interdependent problems.

There are some characteristics of the thinking process which are suitable to transfer content of model object information from the thinking process of responsible human to product model. They are partial decision points on the way leading to the decision on engineering object, stages or elements of thinking process, knowledge that is defined or applied at decision points, methods and procedures that are applied by the engineers (Fig. 3).

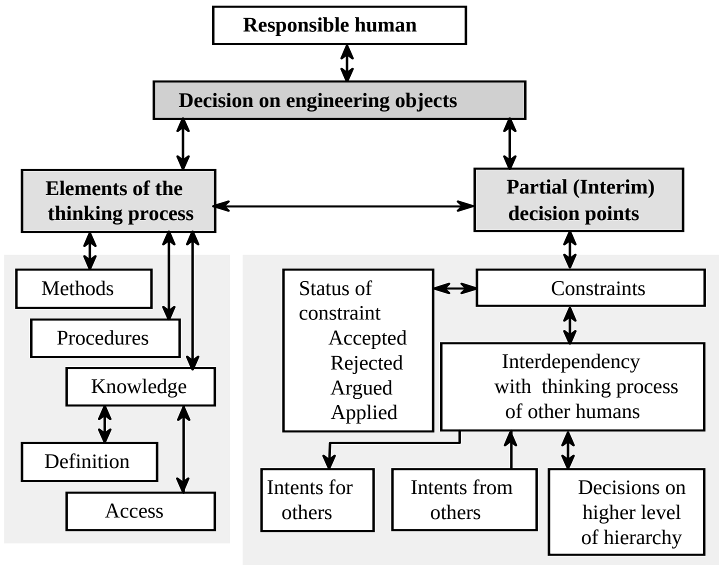

Figure 3
Thinking process at decision

Definition of the above characteristics of the thinking process should provide enough information content for the evaluation and revision of related decisions by human who applies or develops the result of decision making. The human who is responsible for the actual product development that includes the engineering object under definition utilizes problem solving methods and procedures, and defines and accepts knowledge within each element of a thinking process (Fig. 3). Interdependence with thinking process and intent of other humans is realized through received and defined constraints. Responsible human also receives decisions from higher levels in hierarchy. Received and defined constraints may have status accepted, rejected, argued, or applied. In case of status applied, the constraint is earlier decided and the responsibility is held by the relevant decision-maker. Sometimes decisions from higher level of hierarchy may be argued.

Elements of the thinking process and partial decision points constitute the only source of information content for the product model. Sequences for elements of thinking process and partial decision points represent logical routes to the solution. Most of the real word sequences can be built using the elements in Figure 4. In the course of thinking process, engineer observes related physical and logical phenomena, perceives relevant real world information, and retrieves product model and other stored information and information content from the computer system. Engineer also retrieves related information and information content stored in mind as knowledge and fact-like experience. This is the stage A of the thinking process on an engineering object related decision.

Having all initial information, human understands the problem, thinks about it, considers the circumstances, and inferences. This is the stage B of the thinking process on engineering object related decision. In the meantime, human produces results at interim decision points. Human conducts experiments, and evaluates and verifies results then interprets results or goes back to the stage B. Any result is mapped to the actual engineering objects as intent.

Structure of elements of thinking process may be represented in tree or network according to the task. One of the knowledge or fact carriers accepted in the product development and management organization is produced as result at a partial or interim decision point. Intent entities are involved in model of the human intent.

Partial decision points are defined by the human at points where an interim result is considered to record for later use. Sometimes interim decision points depend on elements of the thinking process, sometimes not. Fig. 4 shows a typical example. A goal is produced, and then concepts are placed in taxonomy. Following this, an experience is thought then recorded. Engineer conceptualizes a procedure and a method to be applied in it. Finally, partial results are recorded for rule, dependence, and parameters. Partial decision point information also may be represented in tree or network according to the task. Notice, that the main advancement in relation to a classical product model is the organization of entities together with known background.

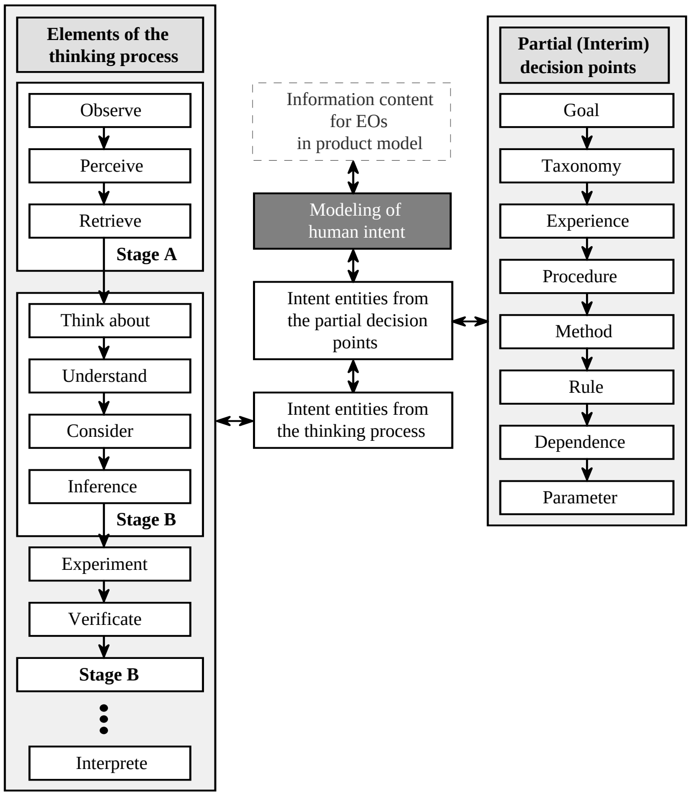

Figure 4
Examples for thinking process elements to record

4 Description of Information Content

It is evident, that information content of product model can be increased only by increasing content of human mind in product model. Information content based product definition is aimed to include reasonable and suitable amount of content of human mind in product model. Connection between information about engineering objects and thinking process of engineer means connection between data and human mind. For this purpose, classification by Russell Ackoff was found as the best suitable one. Ackoff classified content of the human mind into five categories [7]. These categories are data, information, knowledge, understanding, and wisdom. Ackoff characterizes data, as that does not have meaning in itself. In product model space, data for existence of an engineering object, and collection of data for its description are available. According to Ackoff, information is data that has been given meaning by the way of relational connections. Information provides answers to questions who, what, where, and when. Data becomes information where it is connected to its environment in the product model. However, according to its above definition, information is no more than connected data. Attributes are connected within an engineering object, among different engineering objects, and between the product model space and the world outside of it. Information is suitable to assure consistency of product model. It can be recognized that present product model spaces are information based.

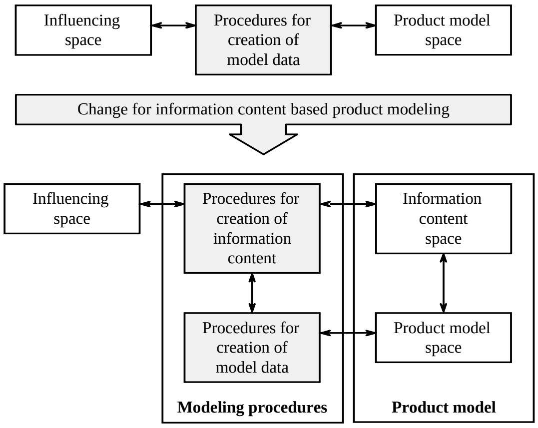

Figure 5
Change for information content

The term classical product model (CPM) was introduced for the product model space that includes information representations of engineering objects for a product and its engineering activities and that does not include content background of the modeled information. The classical attribute refers to an age of product modeling achievements of that has become classical. It is also a tribute to people involved in significant research and development in this area. CPM is theoretically and methodologically complete and well-established system that is appropriate to accommodate information structures that are produced by classical product model generation procedures under the control of information content based model. Creation, relating and modification of CPM is the classical product modeling.

It is obvious that there is a critical prerequisite for the effective assistance of decision making in product modeling. It is the engineer who must know the background of related previous decisions by other engineers in the course of development of a product. When an engineer uses results from earlier product developments in a model-ware, the background must be extended beyond the product under development. For this purpose, information content based product modeling was introduced (Fig. 5) in order to record and apply content of information that is represented in the product model space. Fig. 5 illustrates it by the change from information based product modeling to information content based product modeling.

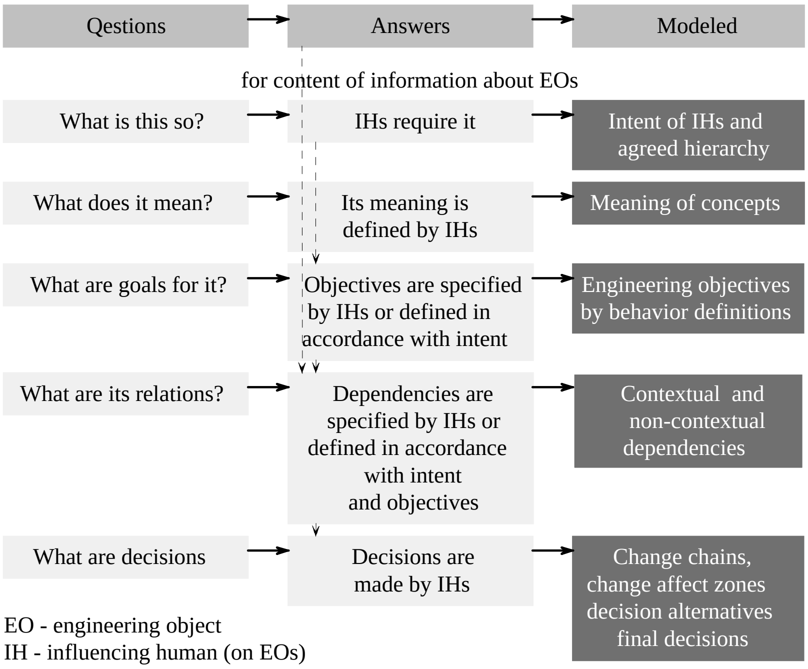

Figure 6
The way to information content definition

Content of information to be included in the product model about engineering objects can be revealed by answers to questions on background of decided engineering object information (Fig. 6). The question about the origin of decision on engineering objects can be answered, as it is required by influencing humans (IHs). Intent of IHs should be recorded together with the agreed hierarchy of them. Definition of intents includes concepts. Meaning of these concepts is the next element of the modeled information content. Engineering objects should match with engineering objectives. These objectives are specified directly by IHs or they come from human intent definitions. An engineering object is defined in the knowledge of information about engineering objects that are in relationship with it. These relationships are generally coming from human intent and engineering objective definitions and their direct definition is also possible. For this purpose, contextual and non-contextual dependencies are to be modeled. Utmost purpose of information content is support of decision making engineering activities. Content is necessary to know about decisions as the basis of control of engineering objects in the product model space. Decision changes engineering objects. Consequences of these changes are change of other engineering objects that are in direct or indirect dependence connection with the originally changed engineering objects.

5 Communication Issues

Information based communication between two cooperating humans in a product development in Fig. 7 shows *that indirect communication through product model is not enough* because product model is not capable of transfer content behind model information. An auxiliary "bypass" out of model communication is necessary. This communication is done by one of the conventional methods and its result can not be used in model and modeling procedures.

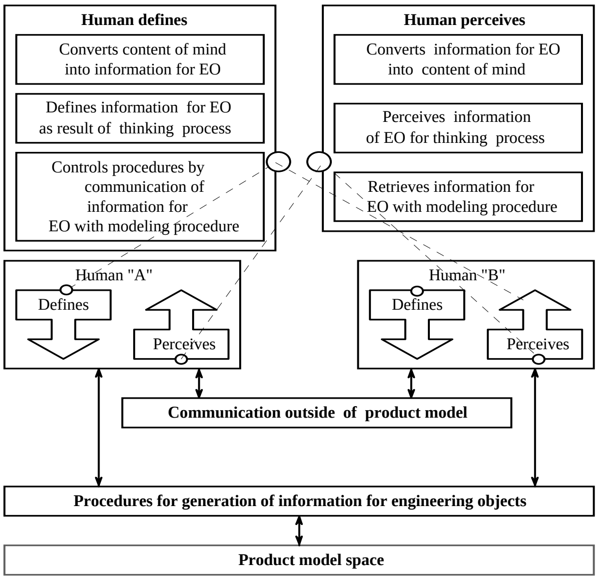

Figure 7
Classical product definition

In the creation of classical product model, human "A" converts content of mind at definition of engineering object into engineering object information while can not enhance product model by the communication of content with procedures. Human "A" communicates information on the dialogue user interface of modeling procedures. A choice of model entities is available and high number of purposeful procedures is applied to generate model information so that consistency of model highly depends on human attention. In this way, human controls procedures at definition of characteristics of engineering objects. Human "B" retrieves information for engineering objects by using of appropriate modeling procedures and receives auxiliary information by conventional communication with human “A”. Human “B” perceives information for own mind and converts it into content of own mind. This communication between humans is two directional and there may be also other participants. This process was identified in order to application at analysis of interface of information based modeling to information content based modeling.

Information based communication between two cooperating humans in a product development was explained in Fig. 7. Fig. 8 explains this communication in case of information content based modeling. Because the main purpose is to record any content that is necessary for any engineering activity, function of the auxiliary “bypass” out of model communication is taken by information content based product model.

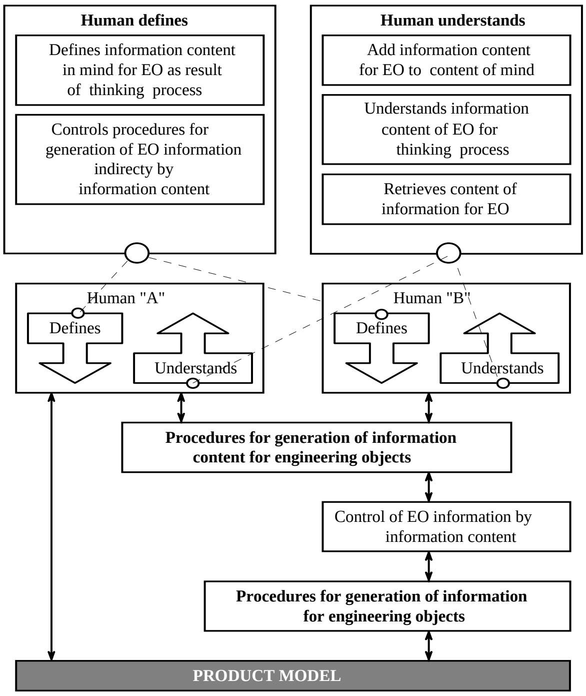

Figure 8

Information content based product definition

Human “A” defines content of mind for definition of engineering object then communicates it with information content based modeling procedures. This content controls generation of engineering object information indirectly. At the same time, human “B” retrieves information content for engineering object on which decides. Human “B” needs information content to assist and constraint decision. The process works also in the opposite direction as it is illustrated in Fig. 8.

It is obvious, that despite some direct definitions, other components of information content must be relied on human intent definition. Otherwise, content behind a decision can not be traced back to human thinking. The solution is to organize the groups of information content in a multilevel model where levels are placed in a hierarchical sequence. Development of information content based model for a product is done along chain of levels. Fig. 9 shows information content as it is defined on each level and its application at the definition of content for the following level, along hierarchy of levels.

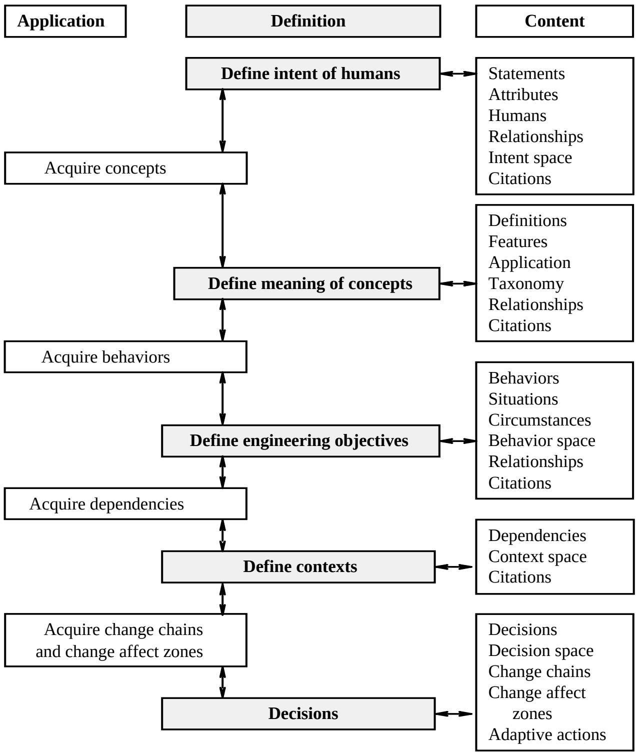

Figure 9
Definition and relating information content

The level-by-level definition of information content is characterized as follows. Influencing humans define their intent based on content of their mind. Intent related content is for statements, intent attributes, humans, relationships, and citations. Meaning of a concept as information content is personal owned and it may include definitions, attributes, application, taxonomy, relationships, and citations. There is not much chance of two humans to define the same concept even if information and knowledge are formally the same. Engineering objectives, contexts and decisions are defined similarly by using of information content on the previous level. Content for engineering objectives, contexts, and decisions are listed in Fig. 9.

Conclusions

Classical communication between two engineers in product development has not the capability for transfer content behind engineering decision recorded as information on engineering objects. An auxiliary "bypass" out of model communication is necessary. In order to avoid this situation and establish a higher level of communication between human and modeling procedure, information content based product modeling was introduced in order to record and apply content of information that is represented in the product model space.

Information content of product model can be increased only by increasing content of human mind in product model. Capturing elements of content of mind during decisions about engineering objects for including them in product model requires connection between model information and thinking process of engineer. This content of mind is used by human during interaction with modeling procedures. Information content of product model can be increased only by increasing content of human mind in product model.

Information content is composed by human intent, meaning of concepts, engineering objectives, contexts, and decisions. Other components of information content must be relied on human intent definition. Otherwise, content behind a decision can not be traced back to human thinking. The solution is to organize the groups of information content in a multilevel model where levels are placed in a hierarchical sequence.

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References

[1] Y. Kitamura, M. Kashiwase, M. Fuse, R. Mizoguchi, "Deployment of an ontological framework of functional design knowledge," Advanced Engineering Informatics, Vol. 18, No. 2, 115-127 (2004)

[2] Chris McMahon, Alistair Lowe and Steve Culley, "Knowledge management in engineering design: personalization and codification," Journal of Engineering Design, Vol. 15, No. 4, pp. 307 – 325, August 2004

[3] J. Renaud, "Improvement of the Design Process through Knowledge Capitalization: an Approach by Know-how Mapping," Concurrent Engineering, Vol. 12, pp. 25-37 (2004)

[4] M. Richardson, P. Domingos, "Learning with Knowledge from Multiple Experts," in proc. of the Twentieth International Conference on Machine Learning, Washington, DC, Morgan Kaufmann, pp. 624-631 (2003)

[5] F. Zhang, D. Xue, "Distributed database and knowledge base modeling for concurrent design," Computer-Aided Design, Vol. 34, No. 1, pp. 27-40 (2002)

[6] Y.-S. Ma, T. Tong, "Associative feature modeling for concurrent engineering integration, in Computers in Industry," Vol. 51, No. 1, pp. 51–71 (2003)

[7] Ackoff, R. L., "From Data to Wisdom," Journal of Applies Systems Analysis, Vol. 16, No. 1, pp. 3-9 (1989)

[8] L. Horváth and I. J. Rudas, "Modeling and Problem Solving Methods for Engineers ",Elsevier, Academic Press, 2004, p. 330

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

[10] L. Horváth, "Supporting Lifecycle Management of Product Data by Organized Descriptions and Behavior Definitions of Engineering Objects," Journal of Advanced Computational Intelligence and Intelligent Informatics, Tokyo, Vol. 11, No. 9, pp. 1-7 (2007)

[11] L. Horváth, I. J. Rudas, "An Approach to Processing Product Changes During Product Model Based Engineering," In Proc. of the 2007 IEEE International Conference on System of Systems Engineering, San Antonio, Texas, USA, pp. 104-109

[12] I. J. Rudas, L. Horváth, "Emphases on Human Intent and Knowledge in Management of Changes at Modeling of Products," WSEAS Transactions on Information Science and Applications, Vol. 3, No. 9, pp. 1731-1738 (2006)