

# A Contribution to Expert Decision-based Virtual Product Development

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***Abstract:** Virtual engineering system is based on product description capabilities for all necessary engineering objects during the lifecycle of a product. Really, the product showed similar features and characteristics in virtual system as it would show after manufacturing at its application. When this system includes expert knowledge for the product development and analysis, decision making on engineering objects can be done in virtual. The authors worked in research for expert knowledge based decisions on engineering objects considering product wide consequences of product object changes. In this paper, some results of this work is introduced including completing the currently applied local knowledge with global knowledge and application of the product level defined global knowledge at coordinated decisions on engineering objects considering product and knowledge object levels in product model.*

***Keywords:** product model; knowledge representation; decisions in engineering processes; global expert knowledge*

## 1 Introduction

These years are the time for moving product engineering activities into product lifecycle management systems where product model is constructed using new engineer tools such as a structure of modeled engineering objects, prototyping activities in virtual, and working in groups. A great assistance in their work is knowledge that is communicated with the product model. Consequently, important research and development is focused on knowledge entities in product model.

Expert knowledge based product definition in virtual engineering systems is sketched in Fig. 1. Authorized engineers use group work functions for communication with the PLM (product lifecycle management) system. Engineering object definition interface serves human communication with engineering object definition processes. Sets of procedures are available for engineering object definition. The resulted engineering object definitions are

placed by engineering object data generation processes in product models using product data management functionality.

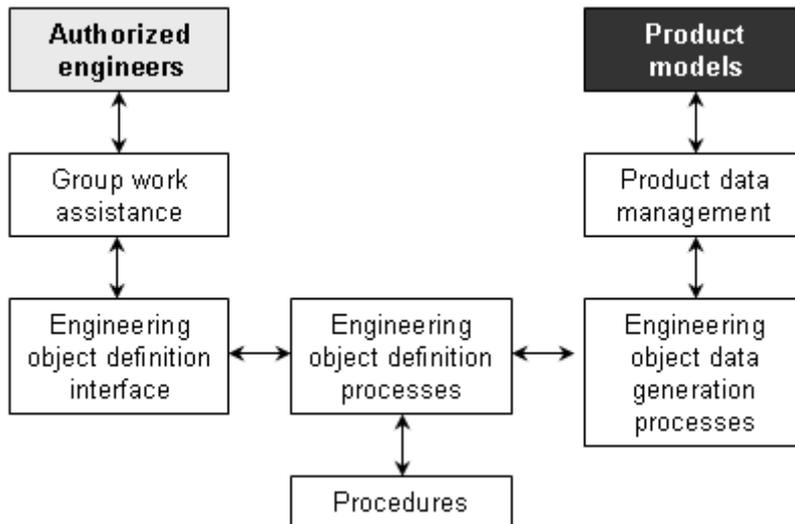


Figure 1. Expert knowledge based product definition in virtual

The authors joined to the research in knowledge driven engineering object decision. They consider starting of their research from a current advanced product modeling and concluded characteristics of these systems and their application for problem solving in [1]. Starting from this point, they analyzed current product modeling, defined it as classical one, and proposed a new content based extension to it [2]. Content is defined by engineers who define product objects in the form of required product objectives and modifications. Modification relies upon features and defined by knowledge in order to give the capability to assist redefinition of product model object parameters in case of changed circumstances.

The results in this paper were introduced as oral talk on the 5th International Symposium on Computational Intelligence and Intelligent Informatics, 2011, Floriana, Malta, 2011 September [13]. This conference was an event in the conference program of IEEE with worldwide participation of internationally recognized researchers.

Standard definition of product model means a capability to accept any engineering object representation necessary for any engineering activity during the lifecycle of a product. Currently, product related engineering activities are also realized outside of the modeling systems with so many known communication and other problems. This is why the work reported in this paper assumes availability of product modeling. Product model was first defined in the object oriented STEP IPIM (Standard for the Exchange of Product Model Data, Integrated Product

Information Model), ISO 10303 product model standard for heterogeneous modeling systems [3]. Product modeling practice applies many methods from software engineering such as agents. An example for the application of agents is an agent-based product and process modeling framework for group work on the Internet in [7].

Including knowledge in engineering purposed programs started from the early expert systems during the eighties. Despite the excellent results, including knowledge representations in model based product definition is still relative slow. Among others, it is a great challenge to produce verified human origin, locally accepted application, experience and skill background, and transparent problem solving process for engineer expert knowledge. This is why expert system characteristics are hard to realize in industrial product lifecycle management systems. One of the challenges in product modeling is development of suitable knowledge definitions for the actual engineering environment.

This paper uses some published basic ideas from the contemporary actual issues and paradigms such as integrated product and manufacturing process modeling [10], models and methods for knowledge formalization that is suitable for lifecycle management of product information [11], and representation of knowledge from multiple experts for product definition [12]. These ideas show the way for future researches. The authors selected a problem complex in which their former results encouraged them.

After a discussion on product structure considering contextual definitions in it, this paper introduces a global product definition where local definitions are replaced by a product wide decision process. Following this, knowledge definition as part of the product definition request is outlined, new entities are explained, and knowledge is related to parameters of engineering objects. Finally, implementation issues and future plans are briefed.

## **2 Product Structure Consisting of Contextual Units**

Product is defined and constructed by authorized and responsible humans who consider outside affects on the product under development. The result is recorded in the product model in the form a structure of engineering objects. Product structure consists of contextual units (Fig. 2). Main elements of a unit are product objects such as parts and assemblies, relationships, analyses such as finite element models and analysis results, knowledge, and models of interacting humans. Dialogue surface is available for human in the graphical viewport of the product modeling system. Object representations are generated by dedicated processes based on procedures both in modeling system and product model. Connections with physical world are established for capture shape, sensor and other

information, and for control production and application related devices and equipment.

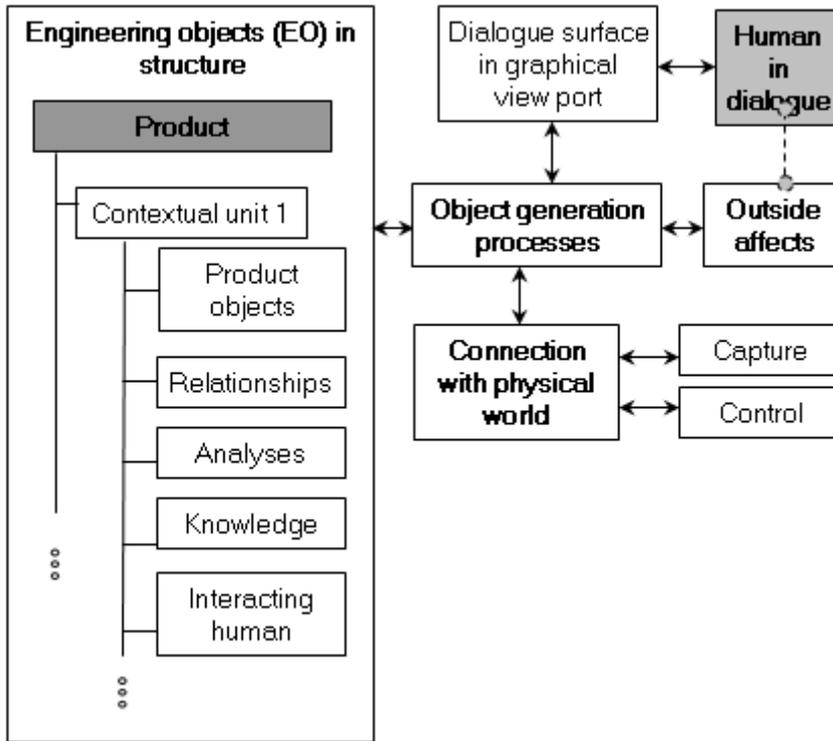


Figure 2. Generation of engineering objects

One of the main achievements in recent developments of product modeling in PLM systems is extending the application of contextual definitions in product models in order to establish a logical structure. The proposed modeling method is full contextual. This means that any object is allowed to define only in the context of other objects.

Contextual definitions must be capable of construction of consistent product model. In this principle, definitions by human are considered as objects in the context of objects characterizing humans. Outside contextual connections can refer to authority for law, higher level decision points in the company or project, etc. Anyway, definition of an object and its parameters is possible only in context. This is also valid for knowledge representations [4].

In the structure of engineering objects, main connections with contextual definitions (dashed line) are shown in Fig. 3. Product object parameters and their sets are contextual with parameters and their sets of other objects. Relationship

and analysis contexts are defined by mathematical functions. Engineer understandable knowledge definitions include context in the form of rule sets, check sets, and reactions handled by algorithms in procedures. Humans interacting physically with a modeled product are contextual with the product model. The related contexts are involved for ergonomic analysis in the scope of virtual prototyping. For this purpose, simplified human representation called manikin is applied for activity, posture and other analyses

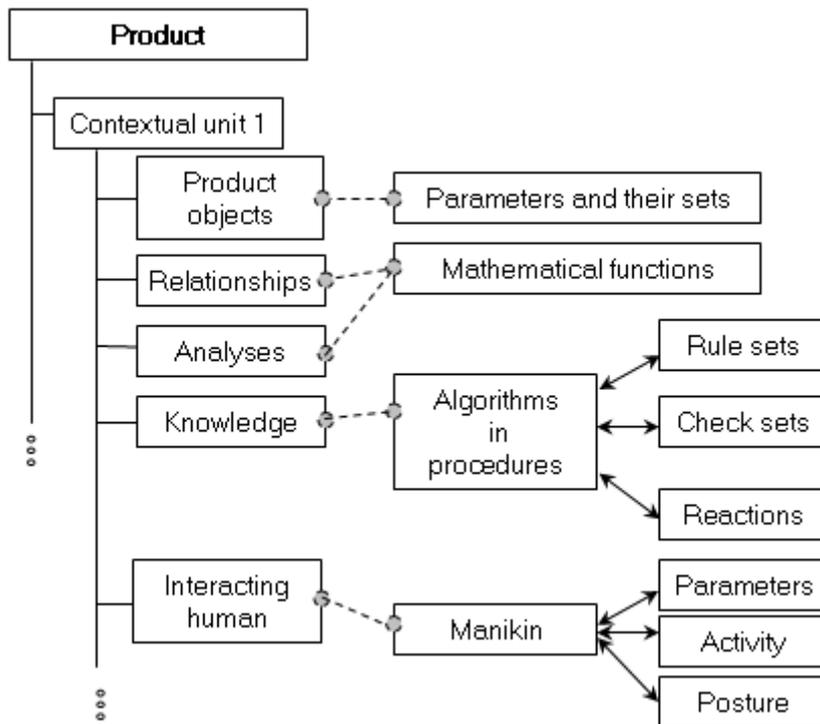


Figure 3. Engineering objects in context

### 3 New Method for Product Definition

Main purpose of the proposed modeling is to eliminate a main drawback of current product modeling in PLM systems. In these systems, decisions are local and use local knowledge. It is impossible to coordinate decisions in product level by using of the product model. A product definition is considered local when a single object or a closely connected group of objects is defined for the product

model considering main affects from outside. This is the case of classical product modeling.

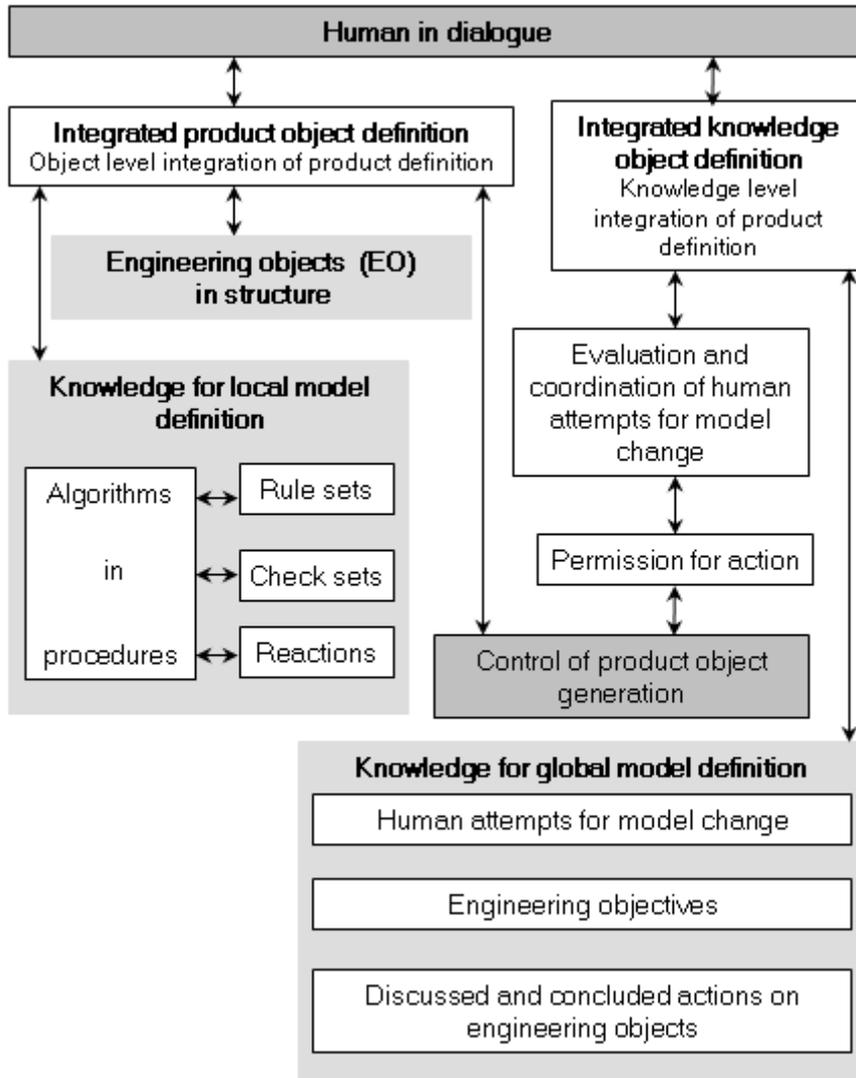


Figure 4. Classical and the proposed object definition

The authors proposed a global product definition where local definitions are replaced by a product wide decision process. In this schema, engineering object representations (EO) in product structure are supported by knowledge both for global and local model definition (Fig. 4). Despite knowledge representations for

the definition of engineering object parameters, integrated product object definition in classical product modeling realizes object level integration only in local product definition. Knowledge serves only local model definition.

In the proposed modeling, global knowledge replaced this direct definition of engineering objects by a product wide decision process. Integrated knowledge object definition placed product definition to the knowledge level. Human dialogue communicates knowledge. This knowledge serves global model definition and includes human attempts for model change, engineering objectives, and discussed and concluded actions on engineering objects. It is in connection with local knowledge definition. Human attempts for model change are evaluated and coordinated. Actions for control of product object generation process at object level product definition needs permission. Permission is generated by successful coordination of human attempts for model change. This control replaces the direct control of engineers. Engineers are still in dialogues with this control, however, they can intervene only by knowledge that explains and represents their intent.

Change request by human initiates the above explained contextual construction process of product in model space. All requests with knowledge behind them are considered. This is inherent characteristic of the proposed method. Knowledge for this global level model definition is represented by the entities in Fig. 5. Human attempt for model change is represented as intent record, product objective request and product definition request. Intent record includes what engineer would like influence. Product objective may be an operating function with specification or a quality with requested measures. Product definition request contains how engineer intend achieve the defined objectives. Engineering objective is recorded for product object behavior in situation defined by circumstances. Multiple objectives on a less or more integrated engineering object are represented in more or less coordinated behaviors. As an example, a movement is the objective and the stiffness of a part is a second objective. Coordination of two behaviors serves to fulfill the first objective. Discussed and concluded actions on engineering objects are represented by affect zones for change requests, change chains, and adaptive actions. All of the above knowledge representation entities are mapped to engineering objects for which they are defined. Adaptive action for realization of engineering object modification may be one of the change requests, parallel realized change requests or a composition of change requests. This is the result of change requests consequences analysis along chains generated using contextual connections between pairs of engineering objects in an affect zone. More details about this process can be read in [5].

The above method was intended as a contribution to finding simple way that is suitable for organizing the high number of contextual definitions during engineering object definition. Really, this is one of the key issues in global product model definition. Example for the related efforts was published in [6] where change propagation paths and their impact on the delivery of a product were analyzed.

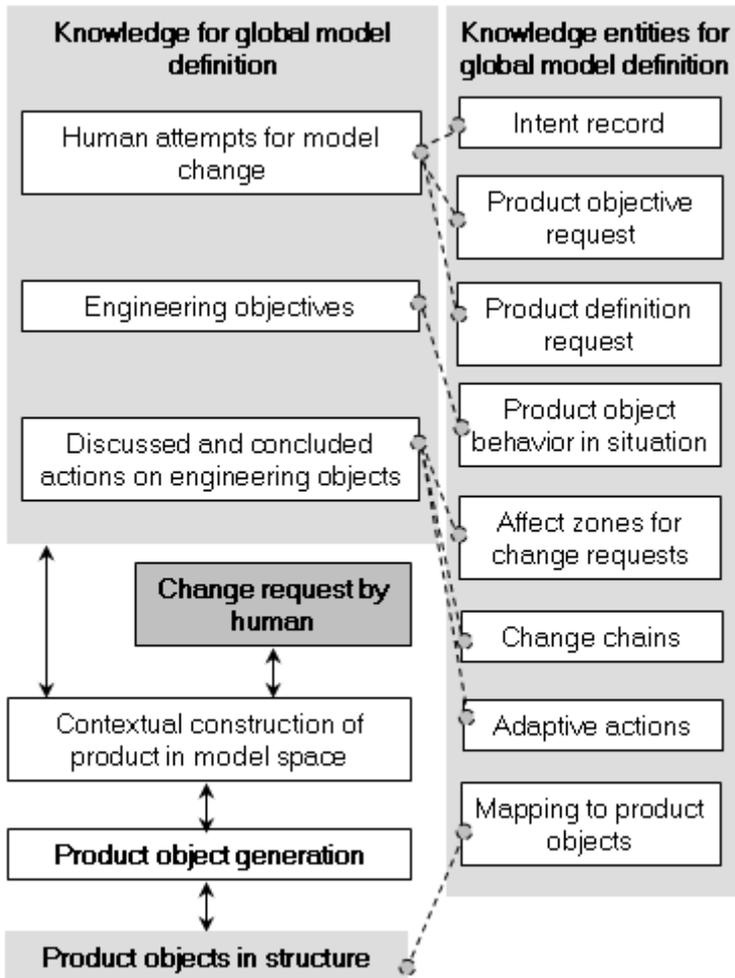


Figure 5. . Knowledge for global model definition

Theoretically, processing of request launched in human dialogue is done on the level of product and knowledge objects (Fig. 6). Launch of requested product objects and their requested parameters is processed in the course of integrated product object definition as in case of classical product modeling. The result is placed in structure of engineering object. However, only checked and approved object information can be processed. This control information comes from integrated knowledge object definition on the basis of processing lunched knowledge for the definition of product objects and their requested parameters.

The most important new stage of the proposed modeling is interactive coordinated decision on adaptive actions. In this process, the increasing knowledge based

support of decisions is the main objective of future developments by the authors of this paper. According to the current level of automation, change chains and CAZ are available in contextual graph together with human request originated, included or linked knowledge. Product object generation and contextual construction of product in model space are done according to adaptive action with executable status as it was explained in Fig. 3. While product definition and prototyping is in the virtual system, executed actions can be withdrawn in case of changed circumstances for product behavior definitions.

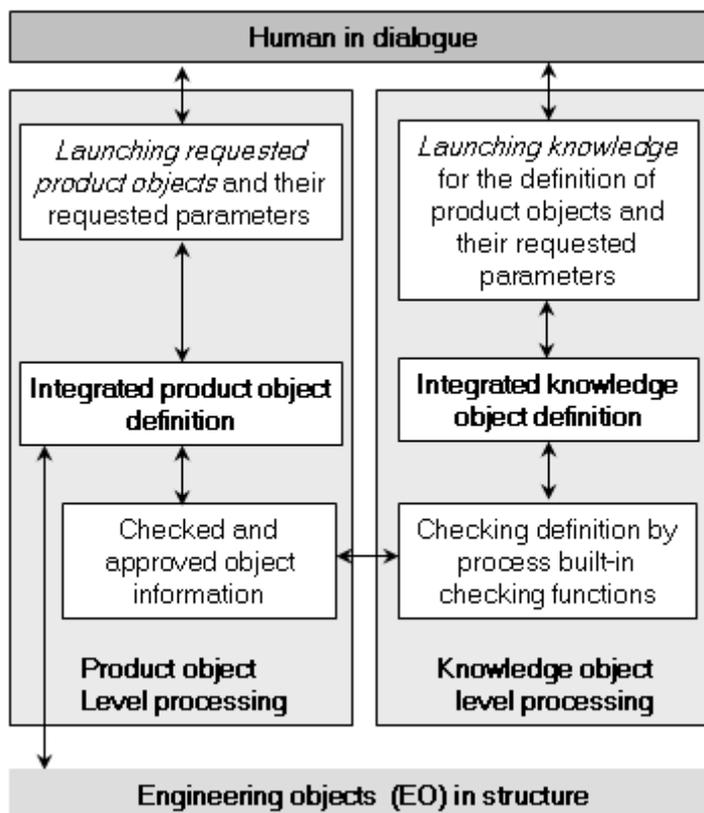


Figure 6. . Product and knowledge object levels

## 4 Knowledge in Product Definition

Authors of this paper established a product modeling in which knowledge carried human intent for decision. This is an important area for research because this is

the point where some of the human intelligence and expertise can be included in the product model in the form of practically applicable knowledge.

The proposed modeling allows for the definition of the same simple and engineer understandable knowledge representations those are applied in recent advanced classical product modeling. In Fig 7, knowledge definition as part of the product definition request is outlined. Knowledge definition is given from the authorized and responsible individual for the modeling at launching knowledge for the definition of product objects and their requested parameters.

Collection of knowledge based definitions is called knowledge ware in leading PLM systems such as referred in [7]. That paper discusses actual issues in modeling, acquisition, storage, management and re-using of the engineer’s knowledge and presents an approach based on the hierarchical structure of design knowledge.

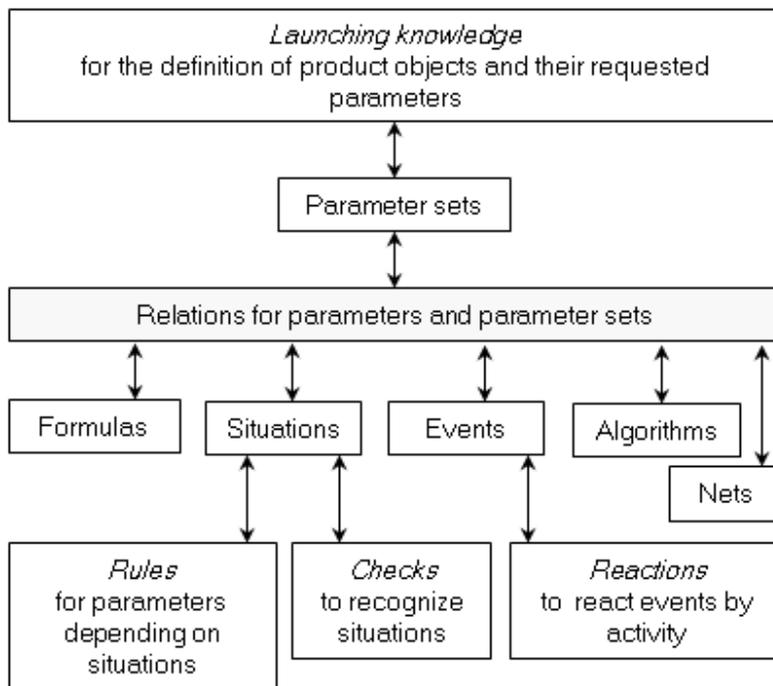


Figure 7. Relating parameters of engineering objects.

Integration of engineering objects, their parameters and relations into sets decreases the complexity of model structure at global product modeling. It is very important that the integrated unit must have the same affect on model such as components would do. The authors of this paper analyzed this problem and proposed solution in [8].

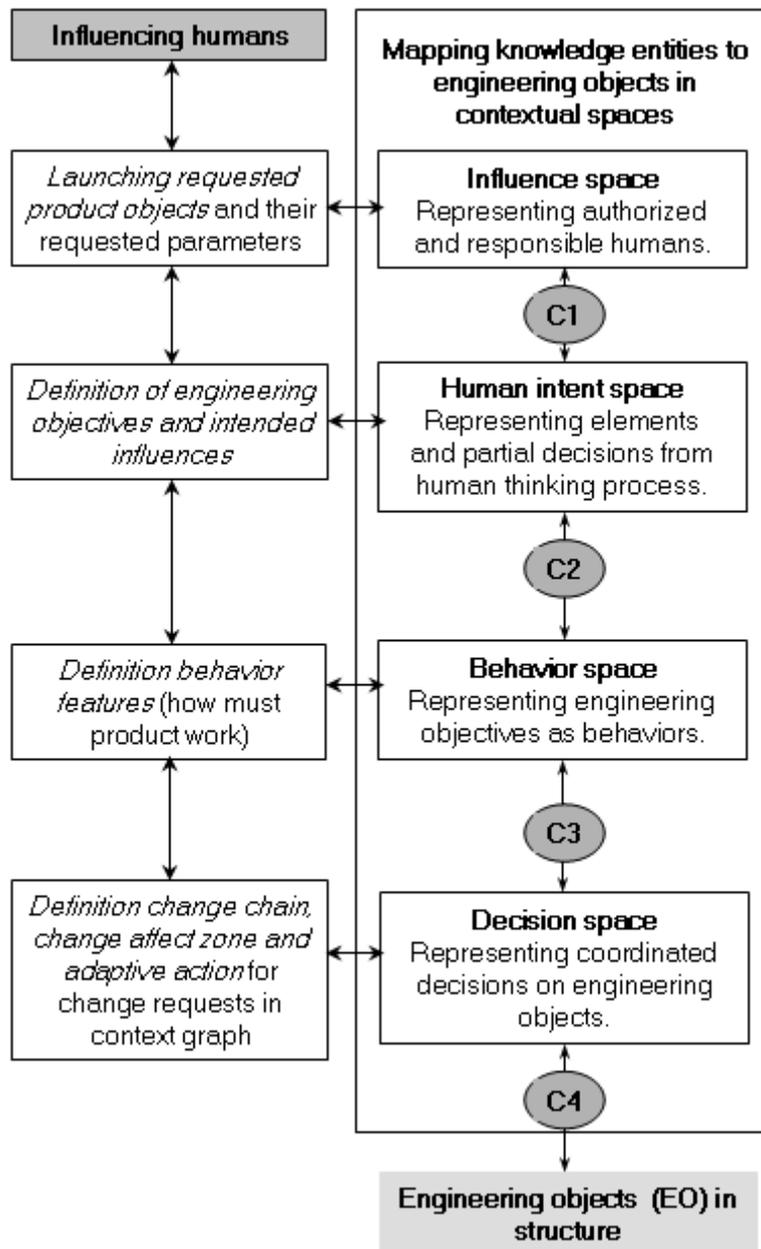


Figure 8. Relating parameters of engineering objects.

In the above scope (Fig. 7), knowledge is defined as relations for parameters and parameter sets. Formulas and algorithms, and net formalisms can be applied

similarly as in classical product modeling. However, definition of these entities is mandatory in the proposed modeling. There may be knowledge items those are not public in the project. For example, expert or other outside advisor launch value or value range of a parameter and explain the proposed solution according to special agreement. However, procedural content of this agreement must be modeled.

The proposed modeling highly relies on situation and event based knowledge representations in order to establish active knowledge that automatically propagates changes in knowledge including situation and event definition parameters. Situation based knowledge definitions are for rules for parameters depending on situations and checks to recognize situations. Event based knowledge entity is the reaction to react events by predefined activity.

Process and representation in the proposed global modeling can be followed in Fig. 8. Launched requests by influencing humans are processed into adaptive action on relevant engineering objects. In the meantime, generated knowledge entities are mapped to relevant engineering objects in order to record the entire background of decisions. For this purpose, four content based spaces are applied.

Requested product objects and their requested parameters are mapped as representing authorized and responsible humans in the influence space. The launched information is applied at the definition of engineering objectives and intended influences. Mapping is done in human intent space where representing elements and partial decisions from human thinking process are referred.

Definition of engineering objectives and intended influences drives definition of behavior features. Behavior space mapping represents engineering objectives for engineering objects as behaviors.

Really, behavior defines how product must work. Behaviors are defined for situations. Situation is composed by actual values of engineering object parameters. This definition can use the above knowledge entities. This method is intended for wide applications in various areas of industry and research, especially in critical processes in case of advanced equipment such as turbojet engine in [9].

Finally, the process of change request harmonization into adaptive actions serves analysis for possible consequence changes of engineering objects those are in contextual connection with the changed engineering objects within change affect zone and along change chains in the context graph. Change affect zone, change chain, context graph, and adaptive action entities are mapped to relevant engineering objects in the decision space. Really, decision space represents coordinated decisions on engineering objects.

## 5 Levels of Consistency

Usefulness of a product model at its application and development critically depends upon consistency. Non-consistent characteristic of model leads to incomplete sets of entities and entity relationships. The modeling process in Fig 8 is governed by the requirement for consistency on the global level of product model definition. Consistency is required for human source, product behavior, and product object (Fig. 9).

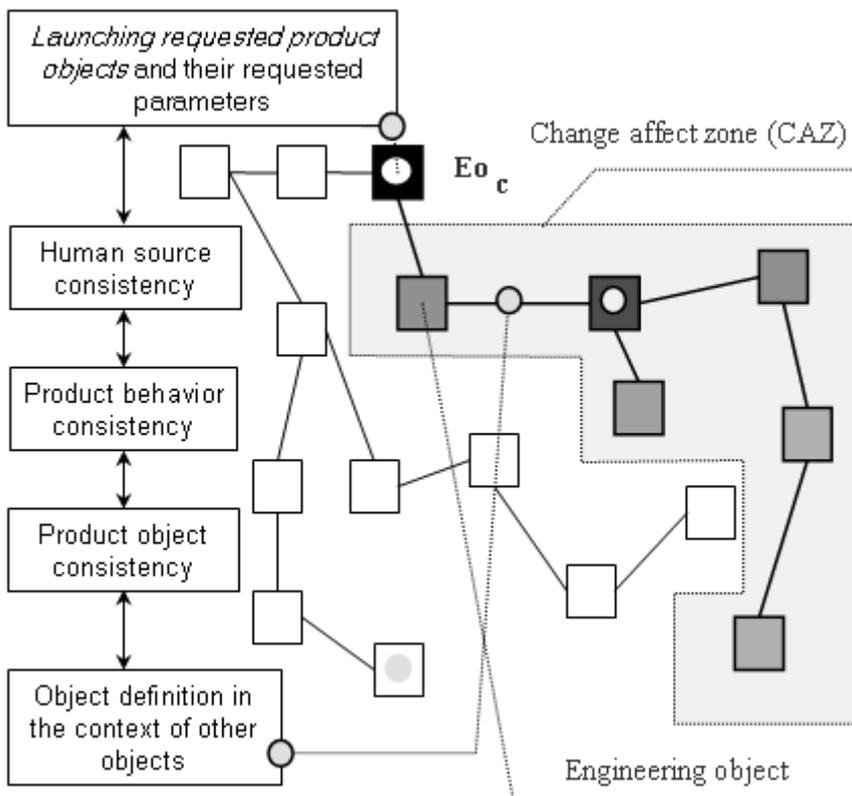


Figure 9. Relating parameters of engineering objects.

Human source consistent the product model when all influencing human has definitions in it and all definitions are mapped to relevant human source. Product behavior consistency means behavior definitions for all engineering objectives while any engineering objective is mapped to relevant engineering object. At the same time, no engineering object definition is allowed without engineering objective definition. Finally, product object consistency means complete structure of part and assembly product objects. This can be extended to form features in a

part. Shape of parts is considered consistent because topology in the widely accepted boundary representation of parts is inherently consistent.

Launching requested product objects and their requested parameters is in connection with human source consistency. Product behavior consistency is the result of launched human influence requests. However, it must be analyzed because it is not the direct consequence of human source consistency. Finally, product object consistency must be analyzed from the side of results in engineering object structure.

An overall request is object definition in the context of other objects as it was emphasized in this paper. Contextual connections are organized in the context graph In Fig.9, change affect zone (CAZ) includes engineering objects those have chance for some affect by change of engineering object  $E_{o_c}$ . In this example, CAZ consists of two change chains.

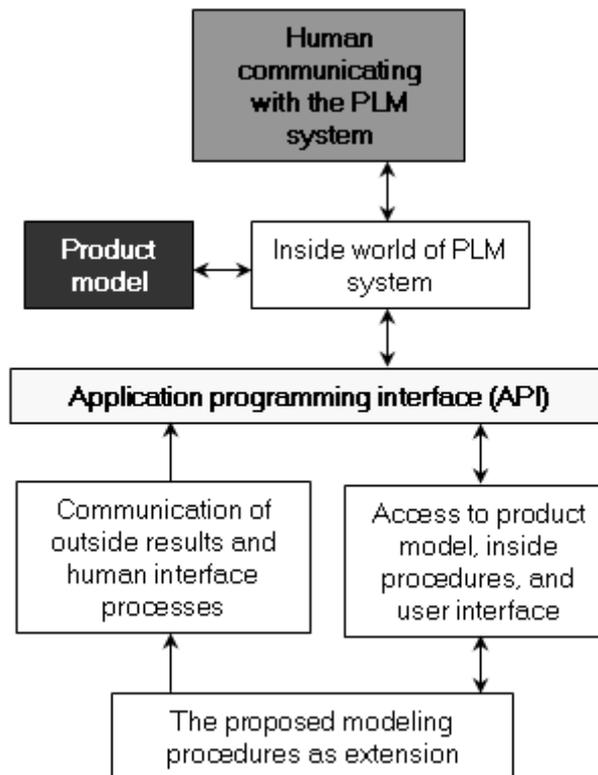


Figure 10. Development on open surface of PLM system.

## Implementation and Future Research

Object modeling in current industrially proved and applied product lifecycle management systems can be extended by using of software development libraries available in the application programming interface (API, Fig. 10). Human communicates with the PLM system in the usual way, utilizing extensive functionality of the PLM system. Inside the world of PLM system, product modeling processes receive and send information through API communicating with the proposed modeling procedures. Outside results and human interface processes are communicated with the PLM system. At the same time, access is provided to product model, inside procedures, and user interface.

Future research must reveal model entities and structures for the implementation of the proposed objects in product models. Analysis and assurance for cooperated consistency of human sources, product behaviors, and product objects will be one of the main issues in future work. Influence of humans and tracking and conflict handling of influences in context graph also will be researched on the basis of results in this paper.

### Conclusions

A new knowledge driven product object definition method is proposed on the basis of well-proven product modeling in current PLM systems. The possibility of development of PLM system in application environments is utilized. The proposed method is part of a research program by the authors. In the proposed method, global product definition is applied to replace the conventional local level definitions by a product wide decision process.

Knowledge for this global level model definition is represented by human attempt for model change as intent record, product objective request and product definition request. Multiple objectives on an engineering object are represented as coordinated behaviors. Discussed and concluded actions on engineering objects are represented by affect zones for change requests, change chains, and adaptive actions. Adaptive action for realization of engineering object modification may be one of the change requests, parallel realized change requests, or a composition of change requests. Global level expert knowledge based product definition provides human source, product behavior, and product object level consistency of product model.

### Acknowledgement

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