New Adaptive Capability for Generic Product Representation

László Horváth and Imre J. Rudas
Óbuda University, John von Neumann Faculty of Informatics
Institute of Applied Mathematics, Budapest, Hungary
horvath.laszlo@nik.uni-obuda.hu, rudas@uni-obuda.hu

Abstract—Very complex and flexible information structure of product representation is essential requirement to cope with firm demands for increased engineering capability and shortened innovation cycle in leading industrial practice. In order to achieve the awaited product model, improved abstraction, behavior, and active knowledge representations constitute the current trend in product lifecycle management (PLM). The Laboratory of Intelligent Engineering Systems (LIES) at the Óbuda University joined efforts to improve self-adaptive PLM modeling ten years ago. In this paper, the request, behavior, action, and context (RBAC) structure is introduced as one of the latest results at LIES. The purpose of the RBAC structure is to collect and manage actual content for generation of elements in the requirement, functional, logical, and physical (RFLP) structure. RFLP structure was recently implemented in leading PLM systems in order to establish multidisciplinary product modeling on the demanded higher abstraction levels. This is development of PLM systems towards systems engineering (SE). This paper introduces a previously published multilevel abstraction based product definition method, its application at the development of RBAC structure, connection of RFLP and RBAC structures, and modeling methods on levels of the RBAC structure.

I. INTRODUCTION

During the last two decades of the past century, key areas of engineering activities were served by partial solutions in the form of CAD, CAM, CAE, etc. systems. The new century brought essential change in engineering systems on a higher level of product information integration and management. The STEP (Standard for the Exchange of Product Model Data, ISO 10303) object-oriented product modeling principle and methodology were developed towards full feature and active knowledge representation driven product definition. The main concern is to establish feature driven modification across contextual chains of feature parameters. Product lifecycle management (PLM) systems are developed dynamically in order to cope with the increasing demand for new model representations and extensive management of product and related information including engineering decisions and their support by extensive simulations.

Other recent change in PLM is to prepare multidisciplinary definition of product features on abstraction levels where product features from mechanical, electric, electronic, hardware and software disciplines are handled by integrated and unified modeling mechanism. Abstraction levels are included in product model in order to better multidisciplinary functional, dynamic, nonlinear, and logical problem solving. In this system sector of PLM model, the requirement, functional, logical, and physical (RFLP) structure was implemented [6]. Modeling in the RFLP structure is an important method in systems engineering (SE).

The work in this paper is based on an early abstraction related work in which background content is represented on five levels of abstraction for the feature based product information. This abstraction structure was published in [1]. Main related works were modeling in integrated model objects [3], behaviors of products [4], and intent of engineers [5]. In order to establish a possible method for knowledge driven assistance of element generation on levels of the RFLP structure, the request, behavior, action, and context (RBAC) structure concept was developed and introduced as one of the latest results at the Laboratory of Intelligent Engineering Systems (LIES, Óbuda University). The RBAC structure collects and manages content for the generation of RFLP structure elements. After an introduction to the relevant PLM related problem and the multilevel abstraction which was published in [1] and applied at development of the RBAC structure, this paper discusses the RBAC structure, the connection of RFLP and RBAC structure elements, the modeling on levels of the RBAC structure, and implementation of RBAC structure in industrial PLM systems.

II. ADAPTIVE CAPABILITIES OF PLM MODEL

After previous important results in modeling of product, efforts for the ISO 10303 [7] object oriented product model standard established the first integrated product modeling method during the eighties and nineties. The resulted product model applied object oriented modeling resources and the feature principle. It was widely implemented in industrial engineering by area dependent application protocols. By now, the feature principle has been extended to the entire PLM model so that product model is full feature driven. As an example, lifecycle definition of features is introduced and discussed in [8]. Feature is included in product representation as object. Arbitrary compatible parameters of arbitrary features can be connected by arbitrary context definitions.

By now, high level integration has resulted very complex PLM systems and models. Similarly to other extensive info communication systems, contributors are increasingly forced to include results in PLM systems. Conventional data interface connections of separated or loosely integrated solutions can not provide the required cooperation with product modeling environments. At the same time, physical, functional, behavior, specification
and other compatibility requirements of products need the modeling and simulation resources of PLM systems. In the future, separated product development and production organizations will not be able to join to companies in leading industrial sectors. An actual problem is discussed in [9] where dynamic structure is proposed in product family modeling in order to produce product variants. For this purpose, knowledge often must be acquired from multiple expert sources for a single model definition activity. Method in paper [10] applies Bayesian network which is used at the structuring of the above input.

Considering the above scenario, this paper concentrates on product specific active knowledge representation in generic product model. Outline of connections in Fig. 1 is aimed to highlight characteristics of the knowledge driven PLM solution. In this way, PLM systems are developed towards virtual engineering systems where any characteristic of the modeled product can be predicted in connection with any other relevant product characteristics. This model will be able to contain any demanded product information including wide range of coordinated simulations. Important simulations proceed and active in real time in order to prevent fatal errors in the model.

Figure 1. General connections in a PLM system

Management of virtual engineering systems is in connection with authorized humans, outside connected sources, feature generation processes, procedures to assist humans at intervention and definition, and PLM data base (Fig. 1). Important outside connections are with job shop level as well as engineering resources as standards, experts, legislation, and outside decisions.

Intervention affects modeling and simulation processes. Definitions are for product features as well as active knowledge features for product feature generation. Feature generation processes create these two categories of features. Situation and event recognition initiate actions for active knowledge entities. In Fig. 1, dashed lines illustrate theoretical-logical connections while real connections are provided through virtual engineering system management. A feature definition actively modifies all formerly defined features which are in contextual connection with the parameters of the newly defined feature. Similarly, active knowledge feature acts on related product features through contextual connections. Because modified features act on all contextual features, a well configured product model automatically updates itself while prevents unsuitable modifications which would result, for example, incorrect geometry or broken constraint.

Figure 2. Classical contextual product definition

Example in the Fig. 2 is a detail of a product model. It shows contextual connections within several product features. In Fig. 2, PF_A and PF_B are product features. Parameter FP_PFBK is defined in the context of FP_PFBI. This contextual connection is provided by the mathematical equation EQ_i. Similarly, parameter FP_PFBJ is defined in the context of parameter FP_PFBI through the equation EQ_j. At the same time, parameters FP_PFAI and FP_PFBI of the feature PF_A are defined in the context of parameter FP_PFBK. This contextual connection is provided by the rule R_n. FP_PFBI is defined in the context of outside control parameter PO_k through the equation EQ_k. The above contextual connections provide situation based control of the relevant features. Example for event knowledge is the reaction R_m which reacts to change of parameter FP_PFBK by an activity. This activity may be control of relevant
features, a notice for the responsible engineer, etc. The above control of product feature parameters were defined as classic product modeling (CPM) in [1]. This definition required because CPM was applied as starting point of the research in higher level abstraction for the RBAC support of multidisciplinary product definition. It was supposed, that a host PLM system provides the resources necessary for solution development in application environments.

### III. LEVELS OF ABSTRACTION

As it was emphasized above in this paper, handling product objects from different discipline areas in a single integrated product model has been inevitable in leading industries. Modeling of multidiscipline products by using of a unified method and executing integrated simulations are key technology elements. In this scenario, for example, central control software, hardware for the operating of this software, electric drive and electronics for its control, and working mechanism in a typical recent product need model in an integrated structure. The demand for higher abstraction levels had been recognized by the authors of this paper when abstraction launched in leading PLM systems [1].

Figure 3. Content driven product definition [1]

Definition of abstraction levels in [1] was the result of a research in modeling of content behind the information in product model. Content definition method was motivated by Russell Ackoff [2] who analyzed content of the human mind and categorized it as data, information, knowledge, understanding, and wisdom. According to this concept, data does not have meaning in itself. Meaning is given by information which is connected data. Content of human mind is carried by knowledge and understanding. They answer questions that how and why, respectively. According to Ackoff, understanding is result of knowledge synthesis. It is obvious that a contextually connected data set in product model represents information [4]. In recent development of PLM modeling, knowledge based abstraction is probably attempt to reach higher level Ackoff’s categories.

The abstraction that is proposed in [1] is summarized in Fig. 3. In this concept, content is carried by product model features in five levels of abstraction. These levels are intent of humans, meaning of concepts, engineering objectives, contexts, and decisions. Levels constitute a contextual chain. The last element of this chain is the decision in which contextual knowledge features drive classical product model features. Product feature is driven by knowledge feature while product feature modifies other product features through its contextual connections.

Because development of PLM modeling in the past five years resulted in successful implementation of the requirement, function, logical, and physical (RFLP) structure, the concept in Fig 3 needed reconfiguration and new definition in order to make its connection with RFLP structure possible. Because leading PLM provides highly connective RFLP structures [6], the above connection is feasible. At the same time, definition of R, F, L, and P elements in current PLM systems is done manually despite the flexible means for the definition of element content. This motivated research in connection of abstraction in [1] with the RFLP structure. Changes in this abstraction are outlined in Fig. 4. Among their recently proposed and published new concepts, the authors of this paper established the request, behavior, action, and context (RBAC) structure. In this context, the aim of this paper is to introduce a content based drive of generic product model in case of well defined situation and event definitions. As it can be seen in Fig 4, four levels of the RFLP structure are driven by four levels of the RBAC content structure. In the engineering practice, this means RBAC content driven definition of RFLP elements and their connections.

Requirement elements are defined on the basis of human requests. Functions are represented on the behavior level and generated in the F level using behavior level content. In advanced PLM, behavior definition is possible in the F and L levels of the RFLP structure. Consequently, behaviors can be generated in these elements using behavior level content. Levels action and context include coordinated content both for the L and P levels. CPM features are connected to P level elements in accordance with the program in the host PLM system.

### IV. NEW METHOD FOR SELF ADAPTATION

Purpose of the request level in the RBAC structure is twofold. One purpose is to communicate the human intent in contextual chain in coordination with intent by other humans. The coordinated content is applied at definition of elements on the behavior level. Other purpose of the request level is to include verified knowledge background.
for the request. Allowable knowledge representations are limited by capabilities of the host RFLP based PLM modeling. However, current PLM systems offer wide range of user defined knowledge representations and knowledge representations can be completed through application programming interface (API).

On the behavior level of RBAC structure (Fig. 6), a formerly published product behavior definition was applied. The novelty of this behavior definition was its extension to all product characteristics [4]. Product behavior is defined in the context of function so that any other request element is accessed through contextual connections with function. Context map is in connection with behavior and includes all definition and context of P level product and knowledge elements. Relevant request parameters are used to compose situations and related circumstance sets in their background. Product behavior context is applied for the definition of actions in order to initiate activities for physical level feature generation.

Self adaptive modification of the proposed model works similarly to the adaptive processes in current PLM systems. When any parameter of any element or any value of any other parameter changes in the product model, contextual connections are activated initiating parameter changes in the model along contextual chains. Element may be of RFLP, RBAC, or classical feature structure. Suitable and correct contextual definitions are essential in the model structure in order to proper self adaptive processes.

One of the challenges in contextually connected elements based product definition is the complexity. High

![Diagram 4](image_url)

**Figure 4.** RBAC content driven RFLP structure

![Diagram 5](image_url)

**Figure 5.** Request level driving

Fig 5 summarizes element types and their contextual connections on the request level. The main driving factor is human expertise. Human decision on request elements is in this context. At the same time, company experience is applied and enriched during these decisions. Accumulated company knowledge must be cited at the communication of request. In advanced engineering processes, essential knowledge is mandatory to use. Product function, quality specification, preliminary product feature, and knowledge carrier method elements are communicated. These elements of request are advised to be interconnected by the contextual connections as it is shown in Fig. 5. Nevertheless, any other suitable connection can be defined. As in case of RFLP structure elements, RBAC structure elements are free to connect within a level and between levels. Product function is contextual with related functions and the relevant behavior. This request modeling is highly based on methodology which was published in [5] and introduced request features and their connections in product model.
number of elements and their connection definitions make the model very hard to survey. The context map on the C level of the RBAC structure is a possible contribution to the solution of complexity problem. Its application at definition and handling of contextual chains is assisted by the concept of change affect zone (CAZ) which was published in [5]. A CAZ starts from a modified element and includes all possible affected elements.

Figure 6. Behavior and action level driving

Context map structure is explained by its detail in (Fig. 7). Three entity types are contextual structure element (ECS), contextual port of an element (CP), and context definition (CD). ECS may be any element which can be related to other element(s). ECS have one or more CPs in accordance with its CD connections. CD can use any suitable and available representations such as logical connection, formula, equation, rule, etc. In Fig. 7, several simple CDs are applied. Simple CD connects two CPs. In case a rule, for example, complex CD may include connection with three or more CPs. This contextual structure organizes the L level element generation for RFLP structures. Entity CPB2 is inactive in the Fig. 7.

V. INTEGRATION IN INDUSTRIAL PLM MODELING SYSTEM

The RBAC structure is intended to implement for the application in PLM systems with and without RFLP structure. When RFLP structure is not available in a PLM system, the classical feature structure is driven by using of product behavior through feature definition actions as it is seen in Fig. 6. Integration utilizes free definition and connection of elements on the levels of RFLP structure in leading PLM.

Integration is outlined in Fig. 8. Depending on the PLM system capabilities, more or less of the RBAC definition can be done using the available user defined entity and modeling activity configuration capabilities. This is inside sector of the RBAC structure (Fig. 8). The rest of the RBAC definition uses application programming interface (API) which provides interfaces to product data, product definition procedures, and user surfaces in the host PLM system. This is outside sector of RBAC structure (Fig. 8).

The virtual engineering system management functionality (Fig. 1) provides role based access to team environment and projects for engineers. This is the only way of human communication with the modeling environment. Recently, representation of model definition activities is available in leading PLM systems. This is available for construction and event initiated modification of product model elements. Other recent capability collects, organizes, and schedules simulations in the PLM modeling environment. Organic connection of the above capabilities with the RBAC structure and its element handling is planned as future research. Challenge is behavior driven product wide control of simulations.

For the future, research to include system of systems (SoS) methodology in PLM seems important. It is stated
in [11] that current PLM handles individual product system while connections with other systems would be similarly important at the selection of these systems and cooperation between PLM and them. As a relevant result, internal and external parameter complexity definitions are applied at SoS modeling in [12]. The low internal complexity demands optimizing few interacting SoS units in short time horizon, while acquisition and expenditure rates show gradual increasing in time in the external complexity optimizing.

![RBAC structure in PLM system](image)

**Figure 8.** RBAC structure in PLM system

VI. CONCLUSIONS

This paper introduces the RBAC structure and its communications as a recent contribution to the development of higher abstraction modeling methodology in PLM systems. Actual problems which need contribution like this are handling of multidisciplinary product models, adaptive control of generic product model in order to instancing for quick product development, and virtual prototyping using expertise and experience based knowledge. The RBAC structure provides a conceptual background of a requested knowledge based generation of RFLP structures. In the centre of the RBAC structure, various behaviors of product are attempted to coordinate in order to achieve transparent drive system for product and knowledge object definition on the physical level of the RFLP structure. Other attempt is for the organization of contextual connections in context map.

It can be concluded from the results in this paper that PLM systems are open for the connection of RBAC elements in order to more or less automation of RFLP element generation. Anyway, higher level organization of requests, behaviors, actions, and contexts proved very important at coordination and processing of human requested specification and knowledge for the future.

ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support by the Öbuda University research fund.

REFERENCES


