Active Driving Content in RFLP Structured Product Model

László Horváth[a*] and Imre J. Rudas[b]

Óbuda University, H-1034, Budapest, Bécsi u. 96/b, Hungary

[a]horvath.laszlo@nik.uni-obuda.hu, [b]rudas@uni-obuda.hu

Keywords: product lifecycle management, multidisciplinary product model, RFLP structure, IBCA structure, knowledge driven product definition

Abstract. Engineering application of advanced computer methods has been developed into product lifecycle management (PLM) which relies upon single but very complex and comprehensive model of product. Recently, generic product models are in the possession of self adaptive capability for the generation their instances considering well defined situations and events. The Laboratory of Intelligent Engineering Systems (LIES) at the Óbuda University, Budapest, Hungary joined to efforts in research for new product modeling methods in this area. One of recent LIES researches targets new methods for requirements engineering (RE) based and relevant company intelligent property (IP) driven generation of elements in requirements, functional, logical, and physical (RFLP) structure based product models. This seems suitable contribution to solutions for unified conceptual modeling of multidisciplinary products. In this paper, discussion of essential problem with modeling increasingly multidisciplinary industrial products in engineering is followed by discussion of recent issues of RFLP structured product model in PLM system. In this context, contributions in this paper are new concept of multilevel abstraction for mechanical and materials engineering centered PLM model, control of RFLP structure element generation by the new multilevel initiative, behavior, context, and action (IBCA) structure, and the integration of IBCA structure in PLM model.

Introduction

Development of engineering systems in computer systems greatly contributed to well-engineered products during the past two decades. This was greatly stimulated by new demands which enforced better and better engineered products, accurate prototyping, and constantly decreasing innovation cycles. It would be impossible to fulfill these demands without powerful engineering modeling systems. The history of model based engineering, simulation, and manufacturing started with the application of mathematical shape definitions, numerical methods in shape related load analysis, and computer controlled production equipment. One of the essential objectives was integration of theory and practice in a model environment which increasingly relies upon high level information and computer technology. The result was the product lifecycle management (PLM) paradigm which conceptualizes information technology support of all engineering activities using single, highly integrated and complex model of product. This generic model serves lifecycle engineering of product families at industrial companies. As a previous milestone, concept and methodology of product modeling were grounded in a giant project for Integrated Product Information Model (IPIM) during the eighties and nineties. This was the basis of the ISO 10303 standard by the International Standards Organization.

While PLM models were developed on the classical way of knowledge based feature driven methodology during the last decade of past century and first decade of this century, mechanical product structures were integrated with, electric, control electronic, hardware, and software units. The separated or only slightly integrated mechanical engineering modeling increasingly demanded multidisciplinary integration. However, unified multidisciplinary model can be realized only on the level of product concept. As a solution, systems engineering (SE) methodology was introduced in leading PLM modeling systems in the form of requirements, functional, logical, and physical (RFLP) structure. At the same time, knowledge in company environment and active knowledge in product model has become much more organized in the form of intelligent property (IP) of company.

The main contribution in this paper is about one of the latest results in multidisciplinary product modeling at the Laboratory of Intelligent Engineering Systems (LIES). The LIES is active in the organization of the Óbuda University, Budapest, Hungary. On the basis of former results in product model integration [1], feature driven product definition [2], and including content behind model information in product model [3], research at LIES turned to the new problem which was caused by the complexity of RFLP structure elements definition in engineer dialogues. In order to integrate requirement originated active driving knowledge content in product model, the new initiative, behavior, context, and action (IBCA) structure was conceptualized and developed. In this paper, PLM methodology related contribution concentrates on new concept of multilevel abstraction in PLM model, driving RFLP structure element generation by the multilevel IBCA structure, and integration of the IBCA structure in PLM model. The main objective is bridging the current gap between human intent and PLM model entity generation in PLM model definition process. This modeling needs new theoretical and methodological content which is suitable for industrial engineering practice.

Essential Problem at Multidisciplinary Product Engineering Modeling

Development, production, marketing, and application of multidisciplinary products need coordination vast amounts of model information and representations for lifecycle. Although contextual connections between model representations of two different discipline related parts or units is possible on the physical level of modeling, integrated definition must be raised to conceptual level of product design. The classical feature driven PLM model (Fig. 1) is restricted for the physical level where physical product objects are represented and connected. Main groups of product features and their information connections are shown in Fig. 1. Feature modifies earlier defined contextually connected features. The well proven feature principle was originally implemented as the Form Feature Information Model (FFIM) in the ISO 10303 standard. By now, leading PLM modeling systems extended the feature principle to all modeled product objects. Features are placed in object model where suitable object classes and taxonomy are defined.

In the classical product model, product features represent parts and their functionally originated elements. Analysis features represent analysis information for product features. Knowledge features are active at product feature definition for lifecycle. Despite of their key role in contextual chains, less attention is paid for material features in classical product modeling. In Fig 1, connections of material features with product, analysis, and knowledge features are emphasized.

Knowledge features actively modify contextually defined product features when well defined situations and events change [4]. Manufacturing features constitute model of manufacturing activities and process in contextual connection with analysis and knowledge features. This concept by the authors of this paper refuses direct connection between product and manufacturing features and enforces their knowledge based connection. This is considered as important theoretical issue in the future development of classical product modeling and will be topic of future research at the LIES. Using decision results at this level, equipment control features receive information from knowledge and product features. Manufacturing system features are controlled by manufacturing and equipment control features. They are also in connection with resource model features. However, resource model is not issue in this paper and is omitted from Fig. 1.

Conceptual level of product engineering needs abstraction on three levels. These levels are requirements against product, functions of products which are appropriate for the requirements, and system of overall logical connections within the whole multidisciplinary product model. For this purpose, recent leading PMM modeling systems introduced a new four leveled structure of product model using the RFLP structure. This is big change because RFLP structure offers possibility of handling product and its model as systems. RFLP methodology is applied from systems engineering (SE).

Research at the LIES revealed that definition of elements on levels of RFLP structure is a new challenge for engineers who use dedicated dialogue surfaces for this purpose in PLM modeling systems. The initiative, behavior, context, and action (IBCA) structure [5] was intended to fill the above gap between the engineer who defines requests and associated knowledge for product definition and the procedures which generate RFLP elements. This work at LIES is very difficult because comprehensive PLM modeling environment is required which is purposed and configured for research on global level of product definition. As it is shown in Fig. 1, global level modeling in IBCA structure is product requirements initiated. The IBCA structure represents active knowledge content and has driving actions on RFLP structure elements. Its utmost purpose is providing engineers with communication surface for the communication of naturally available information with the IBCA structure in order to generate theory and practice conform RFLP structure elements. Dashed lines in Fig. 1 represent contextual connections which are not essential but possible and available. Because IBCA structure is devoted as fully integrated unit in PLM model, it must have connections both to classical feature driven and RFLP structure based model entities. Driving active knowledge relies upon company expertise and experience in a contextual generic product model.

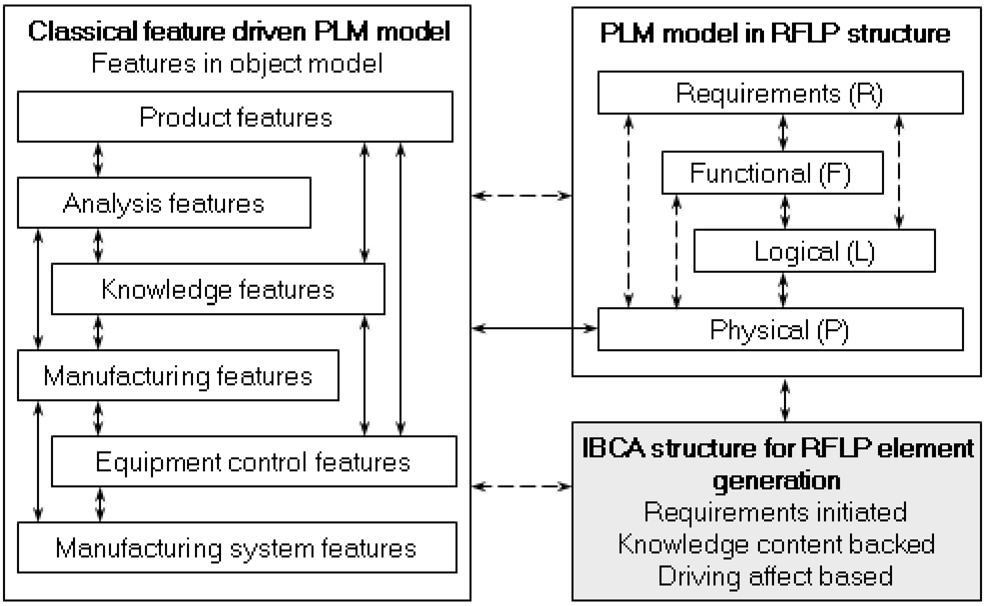

Fig. 1 Place and role of the IBCA structure in PLM model

Including Systems Engineering in the Form of RFLP Structure

As it was emphasized above, conceptual product definition requires high level abstraction and handling product and its model as systems. For this purpose, RFLP structure was introduced in leading PLM technology during recent years [6]. Researchers at the LIES recognized importance of abstraction on higher level than representation of physical product objects in the course of their earlier works. Results were published in [3]. After RFLP structure based product definition was made available in PLM systems, reconsidered and redeveloped version of the abstraction in [3] was analyzed in order to establish content basis for the generation of elements on R, F, and L levels.

Known RFLP implementations [6] had structure which was considered suitable for the IBCA structure. It is important that each level of RFLP structure is also structure in itself. Moreover, additional substructures can be defined as necessary. In order to achieve application related product model user defined elements can be related on levels of the RFLP structure. Ports are opened on element for the purpose of content supply, control, and establishing connections with other elements. Fig. 2 shows ports for content (P_{co}), communication (P_{cm}), and element control (P_{cn}) in case of elements on requirements (R_e), functional (F_e), logical (L_e), and physical (P_e) levels.

The above mentioned redeveloped abstraction levels and their content related connections with elements on levels of the RFLP structure is summarized in Fig. 2. Content for abstraction is placed on five levels. This content is intended to drive RFLP structure element generation. On the first level of abstraction, intent of authorized humans is recorded as required product functions and objects, contextual connections, and demanded or proposed methods for the generation of relevant product objects. This level provides content for R and F level elements. On the second level of abstraction, concepts are included for the interpretation of meaning of new human intent. This is a means of introduction new theoretical contributions for the RFLP structure. On the third level of abstraction, engineering objectives are represented as demanded or proposed behaviors. Behaviors are important because F and L levels in [6] can accommodate various behavior definitions in order to make product model virtually executable. Because recent product models are fully contextual, importance of contextual connections on the fourth level of abstraction for the first three levels of abstraction is inevitable. Context content is communicated with elements on the L level of the RFLP structure. Finally, fifth level of abstraction includes decisions on physical level objects in change affect zones (CAZ) of product model. Concept and methodology of CAZ was published in [7].

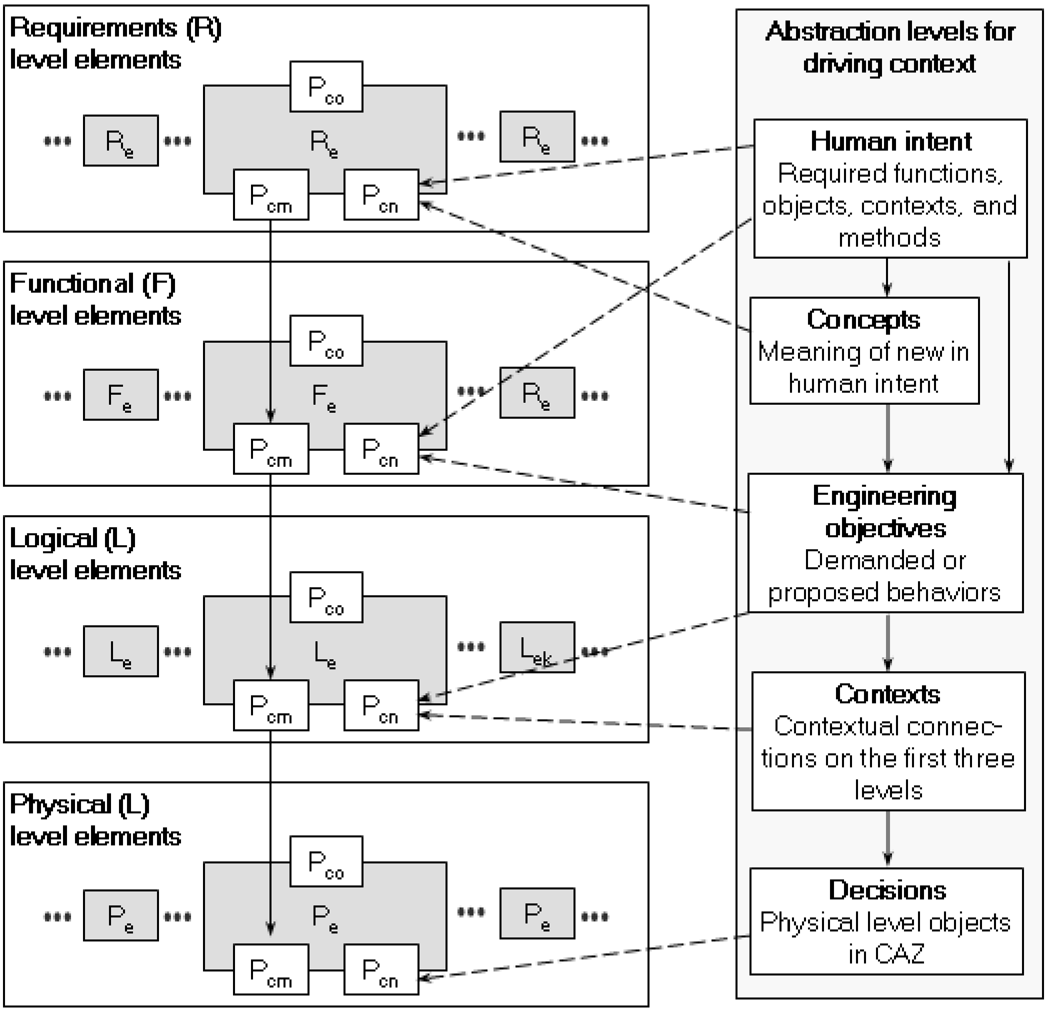

Fig. 2 RFLP structure connections of the proposed abstraction

New Concept for Multilevel Abstraction Based Content in PLM Model

The next question is how the above introduced multilevel model of abstraction content controls generation of RFLP structure elements. First of all, it must be decided how can be modeled this content. As in case of latest classical product models, this control must be adaptive through contextual chains of object parameters and must be maintained for the entire lifecycle of product. The content for driving abstractions is proposed to represent in contextual substructures on the levels of IBCA structure. While definition and connection of IBCA elements are free for authorized engineers, the substructures and their connections are proposed as there are shown in Fig. 3. On the Initiatives (I) level, engineers define elements for initiative definition (DI), specification (SI), product function (FI), product definition method (MI), product configuration (CI), and process of product definition (PI). After initial definition, this level follows changes of accepted and rejected personal originated definitions. In this way, relevant model content is collected in these substructures during the entire lifecycle of product. In this context, product lifecycle starts from the first concept and ends with successful recycling.

On the behaviors (B) level of IBCA structure, definite demands for product are represented in behavior definitions (DB), situations (SB) are configured to define behaviors by a set of object parameter values, and relevant simulations (MB) are defined for behavior analysis. On the contexts (C) level of IBCA structure three categories of contextual definitions are structured for the product model. They are for product definition activity (AC), adaptive drive of model entity generation (DC), and product feature connection (FC). Finally, actions (A) level of IBCA structure serves physical level object definition. Actions are included for product definition activity (AA), adaptive drive of features (DA), and direct product feature actions (FA).

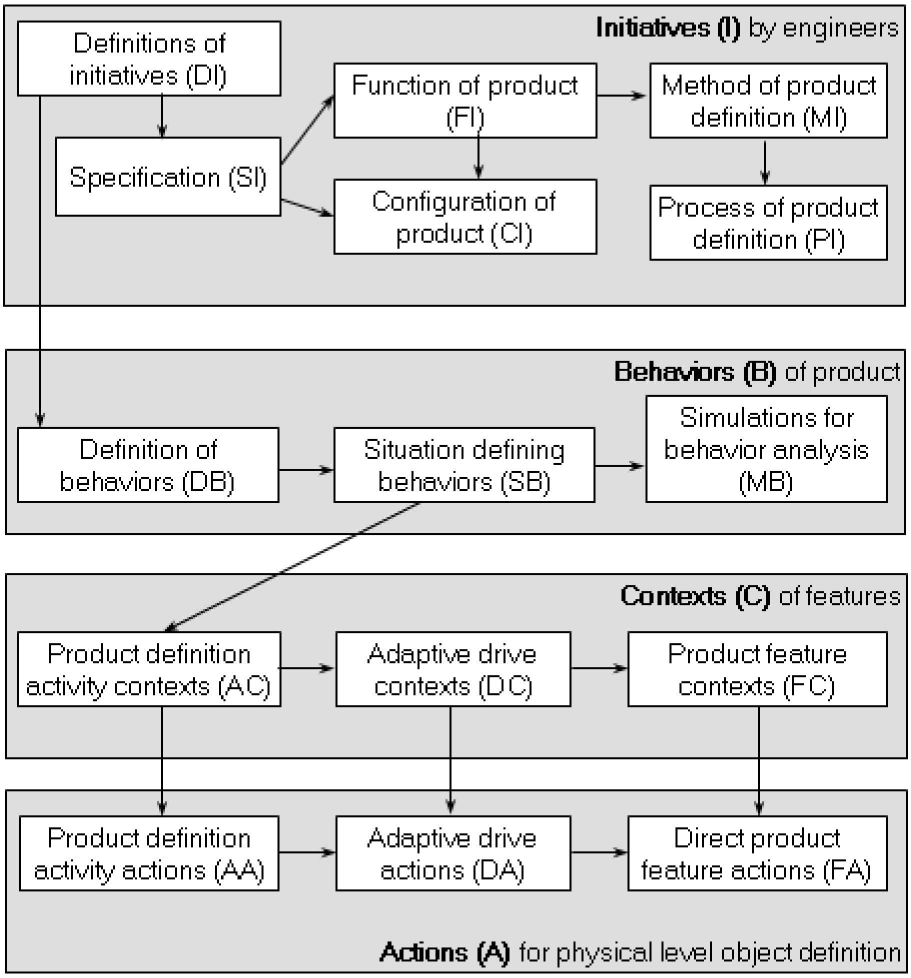

Fig. 3 Contextual substructures of content for driving abstractions on IBCA structure levels

Control of RFLP structure element generation by IBCA structure

As it was stated above, IBCA structure controls element generation for RFLP structured PLM model. Initial basics of IBCA concept were published in [8]. Some advanced structures complete RFLP structure by simulation structures and product definition processes. The latter one serves advanced automation of product entity generation by built in content. At the same time, IBCA structure support is also demanded for classical feature structures where RFLP structure is not available or is not applied at a given PLM modeling. Fig 4 shows driving connections from substructures on IBCA structure levels. Some substructures have not direct driving affect on RFLP structure elements; they act indirectly through elements in other substructures.

On the initiative (I) level of IBCA structure, driving content of DI, FI, CI, and PI substructure elements drive R, F, L, and product definition process elements, respectively (Fig. 4). At the same time, CI substructure elements also can drive features in classical structures. SB behavior (B) substructure provides behavior content for F and L level elements. MB substructure can provide content for simulation structures available in leading industrial PLM technology [6]. Content in context (C) substructures drives L level elements in RFLP structure. Action (A) level substructures drive P level elements. At the same time, FA substructure is capable of providing direct actions on product features as it was discussed above.

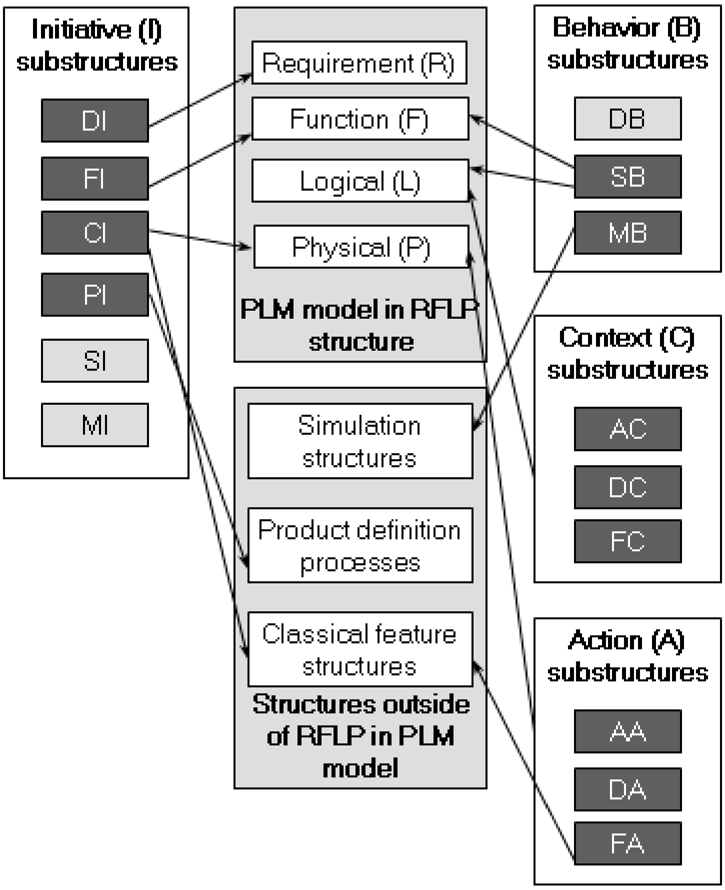

Fig. 4 IBCA structure controlled RFLP structured PLM model

IBCA structure in PLM Model

RFLP based PLM model have a structure which is organized accordingly. The question is how IBCA structure can be integrated in this structure. PLM modeling systems are open for definition of new object classes, parameters, and relationships in contextual connection with existing PLM model entities. In this way, modeling capabilities of PLM system can be extended to IBCA structure. Driving contexts between a pair of elements from the F and I structures in Fig. 5 illustrate active connection between RFLP and IBCA structures. Any change in an IBCA element is propagated in the product model to contextual IBCA and RFLP elements along contextual chains of elements.

During the work for concept and integration of IBCA structure relevant results in related research issues were considered mainly from the area of feature driven modeling, knowledge engineering, soft computing, requirements engineering (RE), and systems engineering (SE). Several of them are cited below. In the future, analysis of application product modeling in system of systems (SoS) engineering environment also must be considered [15].

Paper [9] discusses importance of specific knowledge management tools and proper decisional model for knowledge based definition of product model in order to ensure high design performance. Process of human-computer interaction (HCI) is evaluated in the context of requirements engineering in [10]. HCI functional allocation heuristics is considered in order to control system requirements for decision making. Knowledge based support of design is analyzed in Chapter [14] to achieve organizing design activities, capturing relevant knowledge and embedding this knowledge in engineering model. Authors refer to Dassault Systems V6 system.

One of the actual problems in PLM modeling is application of the highly theoretical intelligent computing in the industrial practice of PLM modeling. Paper [11] discusses how fuzzy logic, genetic algorithms, and neural networks can support engineering activities. On the physical level of PLM model, definition of features and their connections has key importance especially in case of knowledge feature based form and other features.

Paper [12] discusses modification of complex product model through its contextual connections. Large models including units with different types may cause inconsistency. Manual handling of this problem often fails in these systems. Paper [13] shows the way towards automatic inconsistency handling which can generate repair plans using configurable search space and combinatorial type of problem solving.

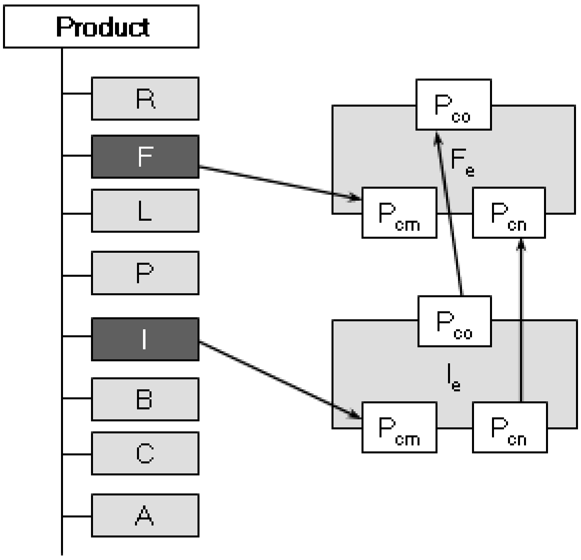

Fig. 5 Connections RFLP and IBCA levels

Because RFLP structure represents new leading virtual engineering technology, it is not available in numerous conventional PLM modeling environments. Moreover, it is subject of project specific decision that RFLP or classical feature structure is developed. Sometime classical solution is enough for an actual engineering task. For this purpose, direct drive of classical product feature structures using direct product feature actions (FA) substructure elements is explained by the example on Fig. 6. In this example FA elements act through four contextual connections for driving PF1, PF2, and PF3 product features in a subset, formula F1, rule R1, and reaction Re1. Parameter P1 is defined in the context of form feature PF1 while PF2 is defined in its context. Rule R1 is also defined in the context of F1 and PF3 is defined in its context. Reaction Re1 is also defined in the context of FF3. In the industrial classical PLM modeling, rule connects a set of feature parameters and activities while reaction recognizes communicated or sensed event.

Although the simple knowledge entities on Fig. 6 are understandable for mechanical and materials engineers, this method makes definition of complex knowledge based adaptive structure along much more complex contextual chains possible. In case of RFLP structure based model, authorized engineer defines these knowledge features and their contextual connections on physical level or raise them to higher abstraction levels. This is a task dependent important decision.

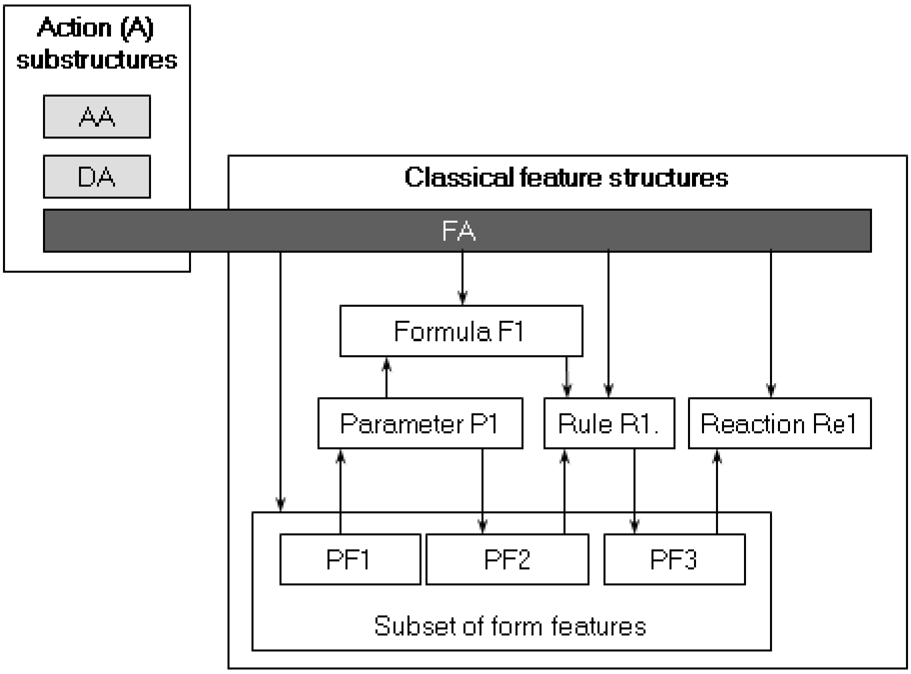

Fig. 6 Direct control of classical feature structures

Implementation and future research

Important preliminary of the research in this paper provided systemic analysis of classical PLM modeling methodology [9]. LIES and former laboratories installed the Dassault Systemes V6 PLM system and its former V4 and V5 versions as leading representative PLM modeling environment. Currently, installation of research configuration of this system is under preparation for IBCA experiments at LIES. Integration of IBCA structure is planned in close connection with RFLP structure. The main objective is application of advanced element and feature definition, and PLM model structure configuration capabilities of PLM system for IBCA model development at application environment. The remained modeling will be considered as development through application programming interface (API).

Future research will start with experimental driving chains between representative IBCA and RFLP structures. A good example for this research is RFLP structured model of robot system using content in IBCA structure. Content communication needs analysis of requirement representation capabilities of IBCA structure and comparison of user surface characteristic in IBCA and RFLP structures.

Summary

Conventional mechanical and materials engineering concepts, methods and processes should be revised in order to prepare the change for PLM modeling of multidisciplinary products. Fortunately, advanced PLM systems rely upon modeling methodology in which modeling and simulation of mechanical structures together with associated materials engineering related modeling are in the centre. Higher level abstraction in RFLP structured product model offers solution for multidisciplinary modeling on the level of conceptual product design. However, conventional dialogue based definition of RFLP structure elements is made almost impossible when complex content including complex knowledge must be handled. The IBCA structure concept of representation active driving content for RFLP structure elements may be one of the possible solutions. Its structure conforms to both RFLP structured and conventional feature driven PLM modeling. Moreover, it can serve as a new connection between these model structures.

References

[1] L. Horváth, I. J. Rudas, Virtual technology based associative integration of modeling of mechanical parts. Journal of Advanced Computational Intelligence and Intelligent Informatics, 5(5) (2001) pp. 269-278.

[2] L. Horváth, I. J. Rudas, S. G. Tzafestas, Relating Shape and Robot Process Model Features. International Journal of Mechanics and Control, 4(2) (2003) 27-31.

[3] L. Horváth: A New Method for Enhanced Information Content in Product Model. WSEAS Transactions on Information Science and Applications, 5(3) (2008) 277-285.

[4] A. Brière-Côté, L. Rivest, A. Desrochers, Adaptive generic product structure modelling for design reuse in engineer-to-order products, Computers in Industry, 61(1) (2010) 53–65.

[5] L. Horváth, I. J. Rudas, Active Knowledge for the Situation-driven Control of Product Definition, Acta Polytechnica Hungarica, 10(2) (2013) 217-234.

[6] S. Kleiner, C. Kramer, Model Based Design with Systems Engineering Based on RFLP Using V6., in: M. Abramovici, R. Stark (eds.) Smart Product Engineering, Springer, Berlin, Heidelberg, 2013, pp 93-102.

[7] L. Horváth, I. J. Rudas, J. Bitó, G. Hancke, Intelligent Computing for the Management of Changes in Industrial Engineering Modeling Processes, Computing and Informatics, 24 (2005) 549-562.

[8] L Horváth, I. J. Rudas, New Method for Generation of RFLP Structure Elements in PLM Model, in: New Trends in Software Methodologies, Tools and Techniques, IOS Press, Delft, Netherlands, 2014. pp. 310-324.

[9] Y. Bodeinab, B. Rosec, E. Caillaudd, “Decisional Model for KBE Implementation in a Commercial CAD Software, Computer-Aided Design and Applications, 9(2) (2012) 121-131.

[10] A. Sutcliffe, S. Thew, P. Jarvis, Experience with user-centered requirements engineering, Requirements Engineering, 16(4) (2011) 267-280.

[11] K. M. Saridakis, A. J. Dentsoras, Soft computing in engineering design. A review, Advanced Engineering Informatics, 22(2) (2008) 202–221.

[12] J. Lee and D. Muthig, Feature-Oriented Analysis and Specification of Dynamic Product Reconfiguration, in: M. Hong (Ed.), High Confidence Software Reuse in Large Systems, Springer Berlin, Heidelberg, 2008, pp. 154-165.

[13] M. A. Almeida da Silva, A. Mougenot, X. Blanc, R. Bendraou, Towards Automated Inconsistency Handling in Design Models, in: C. Salinesi, M. C. Norrie, O. Pastor (Eds.) Advanced Information Systems Engineering, Lecture Notes in Computer Science, Springer Berlin, Heidelberg, Vol. 6051, pp 348-362 (2010).

[14] M. Hirz, W. Dietrich, A. Gfrerrer, J. Lang, Knowledge-Based Design, in: Integrated Computer-Aided Design in Automotive Development, Springer, Berlin, Heidelberg, 2013, pp 309-330.

[15] L. Horváth, I. J. Rudas, Towards interacting systems in product lifecycle management, In: proc of the 8th International Conference on System of Systems Engineering (SoSE), Maui, Hawaii, USA, 2013, pp. 267-272.