Situation Based Control of Product Object Definition

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Abstract—Joining to recent research works for better control of product definition in model space, the authors of this paper developed a novel approach and concept for the methodology of situation based control in contextual object definition. The main purpose of the proposed modeling is improved active knowledge driven definition of product features. In the currently applied industrial product modeling, human defines rule sets and other relationship features as active entities during construction of product model. In order to improve this current technology, the proposed modeling applies human defined and coordinated knowledge for the generation of relationship features establishing a higher level communication surface for humans who define product in model space. Currently applied situation based control of product object definition is completed by adaptive change representation definition of which is human request initiated, situation driven, and knowledge based. New definitions are proposed for situation and knowledge. Process of the situation driven product object control is outlined.

I. INTRODUCTION

Product modeling is main technology in computer mediated engineering where all product information is represented in a structure of features. Product model includes waist number of unorganized relationships in the current industrial practice. Including any new or modified feature in product model requires revision of features those are in direct or indirect relationship with it. When the relationships are included in the product model as active knowledge carriers, this revision may occur automatically. Recent product models apply active relationships in the form of rules, checks, and reactions.

Active relationships in the current product models are features those are defined by the engineer who is working on an actual model development activity. No organizing tools are available so that connections of relationships should be handled mainly by the engineer. Current advanced product definition is considered as situation based definition of features because it is rule based. Although a set of rules is defined for situation, the situation itself is not defined. In excess of unorganized relationships and undefined situations, the third problem with current product modeling is lack of coordination of parallel definitions from different engineers for the same product features. Finally, a higher level decision for the selection of features for product functions including coordination of opinions of different authorized engineers would be necessary for quick and precise decisions on features during development of product model. The authors of this paper have been working on a higher level of product feature definition in order to achieve some contributions to solve the above problems for several years. Initial basics of this modeling were published in [1]. In this paper, recent work by the authors on a novel approach and concept for the methodology of situation based control of contextual object definition is reported as part of modeling for higher level of product feature definition.

Product modeling in this paper considers two main paradigms developed during the past decades. One is the product lifecycle management (PLM) [10] that integrates all information for engineering activities necessary for a product in its lifecycle. The second paradigm is product model as it is defined by Standard for the Exchange of Product Model Data, ISO 10303 [11].

The modeling development work by the authors assumes recognition of always latest technology of the modeling practice with which the proposed higher level of product feature definition should cooperate. In order to achieve a laboratory environment that is appropriate for this, representative product modeling system was installed in the Laboratory of Intelligent Engineering Systems (LIES) at the Institute of Applied Mathematics.

This paper introduces the situation based control of contextual object definition during product modeling. Placing the introduced work in this larger research, the situation based methodological elements are explained from the human defined engineering objectives to the generation of active features in the currently applied product model. In the proposed method, human request initiates situation based adaptive change of product object structure in order to establish situation driven and knowledge based method, solution specific definitions are proposed for situation and knowledge.

II. SITUATION BASED CONTROL OF CONTEXTUAL OBJECT DEFINITION

Control product object definition by situation is a recently achieved technique in product modeling. Currently, situation is defined implicitly in the product model in the form of rules and other unorganized relationship representations. The authors of this paper made an attempt to characterize situation for organized relationships by using of appropriate knowledge in [8]. For this purpose, they extended the conventional situation definition in order to cover all product specifications. An example in [8] is a swept surface in part geometry. In this case, shape and continuity in the boundary of part act as behaviors. Situations may be composed for these behaviors by parameters as generator, path, and spine curves and continuity with mating surfaces in the
boundary. Situation is considered as task dependent and can be defined only during the generation of generic or instance parts.

Recently, extensive rethinking of the concept situation can be experienced in publications. As a good example for recent works in utilization of situation at decision, authors of [2] introduce task dependent context-aware decision support where situation awareness modeling is considered. This environment offers event classification, action recommendation, and proactive decision making. It is very important to decide that how situation is formalized. In order to provide situation awareness for appropriate semantics, authors of [3] introduce an application of Barwise’s situation theory by description of the classes and the properties in ontology.

Figure 1. Situation in modeling

The authors of this paper concluded a situation definition for their modeling. This definition is sketched in Fig. 1 by using of its main connections. Situation is ever-changing during the lifecycle of a product. It is modified by changing the relevant outside world. Outside world acts through well-defined environmental effects, by information for thinking process at authorized humans, and through active knowledge for product object definition. Humans continuously improve environmental effect definitions and active knowledge as the way for increasingly autonomous work of situation based product object control. Environment and human initiated changes of product objects and their parameters in structure of product object representations is controlled by definition of situation using actual and ever-changing set of circumstances. Direct changes by environmental effects, authorized humans, and active knowledge are necessary to complete situation control. More advanced situation control results less demand for direct control. Behavior of product is often defined in variants in order to assist definition of product in customer or problem demanded variants.

One of the relevant topics in the modeling proposed by the authors of this paper is requirements. Paper [4] discusses the problem caused by the need for requirements definition to dynamically changing environmental contexts. This is necessary because changed context needs changed requirements. This is increasingly valid for product definition. On the other hand, engineering decisions must be sensitive of changed environment. This is one of the most important benefits of integrated contextual modeling. Actuality of this problem at the method proposed in this paper is given by the aim for self adaptive features of product model. In excess context, there are aspects to be considered such as working group, source of information, and changes in physical environment.

Figure 2. Current situation based control
A working group related problem is discussed by the paper [5]. The problem recognized is the difference between goals and final design of product due to the distributed characteristic of working groups. This is why validation of the final design against goals is necessary. Paper [5] introduces a formal approach to this task emphasizing the importance of automation the tedious work in case of the current complex products.

The proposed situation based control

While change of parts during the lifecycle of a product is important for the continuous product development, it may cause problems in assembly relationships. Authors of [6] propose an assessment model for relationship analysis as well as part, supplier, and solution selection considering quality, operation and cost, and by the application of liaison graph, fuzzy and value engineering.

Product development proceeds in a changing physical environment. By the development of sensing devices and their intelligent networks more emphasis is on knowledge for processing information from the physical world. An example for this problem is provided by [7] in the topic of reliable work of robots under uncertainty. Authors of [7] propose a robot system that combines knowledge about outside world structure and modeling the uncertainty in a world probabilistically. Probabilistic relational model integrates general knowledge with local observations.

Situation based control of product object definition in current industrial product modeling systems is briefed in Fig. 2. Authorized human defines product objects. In recent modeling systems, active product object relationships can be defined for automatic generation or modification of product objects. Consequently, product object definition directly controls the product object representation generation. At the same time, product object relationships generation updates objects when relationships or values of related parameters in them change. The above object generations are contextual. This means that object parameters are defined in the context of other object parameters. In this level of situation based modeling, relationships carry situation information. Most important relationships are illustrated in a structure of object representations. The structure is for product P1. Product objects are placed on n levels. In the example structure on Fig. 2, L1Po means a product object on level 1, and so on. Rule y in the rule set x (R\(x\)Ry) gives relationship between parameters of objects L1Po and LnPo. Parameter Pz is defined for L1Po and applies formula Fq. Fq represents connection between parameters of LiPo and LnPo.

The authors of this paper proposed product object relationship generation functionality representing control of situation based object definition using a new knowledge based method. This new scenario is shown in Fig 3. Directly defined product object representation and product object relationships generation are replaced by authorized human initiated launches of modification requests. Arbitrary amount and content can be launched by different authorized humans for the same purpose. Request object definition generates request object representations. Request is based on specification of requested objectives and the proposed methods for object definition. Objectives and methods are represented in the form of situation based behaviors. Requests for the same and different product objects are coordinated by using of product model wide analysis of consequences.

Situations are defined for behaviors by appropriate object parameters and product object parameters are defined for actual situation by using of adaptive change representation. Contextual object generation including product object representation generation and product object relationships generation is done by using of adaptive change representation. Currently applied product model in Fig 2 is to be completed by new entity structure for request initiated adaptive product object definition. New entities are mapped to currently applied model as it was conceptualized in [1].

III. DEFINITION OF SITUATION AND ITS APPLICATION FOR CONTROL

In the proposed modeling, situation is applied as a set of parameters called as circumstances characterizing a product object consideration demand for a related engineering task. It is collected from different authentic sources and applied as an integrated specification of a
behavior. Definition of situation for the proposed modeling is explained on Fig. 4. In excess to the human launch, request object definition (Fig. 3) has also input from outside contexts. Request object definition generates function, quality, product object, and method entities. These are sources for circumstance generation. Circumstances are completed during product object definition and the related knowledge acquisition.

As it comes from the above stated basics, circumstance defines an actual situation for a behavior in a product definition task. Task depends on the engineering work distribution and involves less or more complex function and relevant quality specification. Processing of task may result a single part or a group of parts according to the assigned work in the relevant project. Consequently, product definition is initiated in the form of contextual tasks. In the other hand, it can be seen from the above explanation that behavior is task oriented and its content is defined during construction of model by product definition. Contextual structure of behaviors also can be used for the definition of functional structure in current advanced industrial product models where parts and assemblies of product are connected by functions.

Product object $PO_{BA}$ is defined for $BH_A$. Product objects are organized in a contextual structure where they are defined for product object structure together with their contextual connections. Behavior initiated change information for product objects are carried by adaptive action. In Fig. 5, adaptive action for $BH_A$ controls product object $PO_{BA}$ through contextual connection $C_{AA}$. At the same time, $PO_{BA}$ has three contextual connections ($C_X$, $C_Y$, and $C_Z$) with other product objects.

Because behavior is the object that controls product definition, it can be carried between product models and can be brought in a product definition task. It may control single, complex or group objects in the contextual structure of product objects. With its above detailed and explained definition, behavior is one of the main original contributions to product modeling by the authors of this paper. It must be remembered any circumstance may have any contextual connection with any other circumstance. However, these contextual connections are organized into contextual connections of behaviors in the proposed modeling.
IV. ACTIVE KNOWLEDGE

Control in Fig 5 is driven by active knowledge in request representations considering actual status of each request. Definition of knowledge is fitted to its engineering application. Any request representation that is mandatory, advised, or proposed to consider at decision on product objects is handled as knowledge. Consequently, this knowledge definition is more widely scoped as it is usual in academic areas.

The authors of this paper considered knowledge as something that comes into the modeling by one of the organizational human filters. Because knowledge must be accepted for a less or more extended engineering task, it was decided to include in product model in active function. Active means that product object parameters are defined in the context of knowledge. Consequently, when a knowledge entity or information in it for parameter value of some product object changes, the relevant product object parameters change in accordance with the new or modified knowledge entity.

A knowledge model recently proposed by the authors of this paper is outlined in Fig. 6. In this model, human applies expertise at request activities. In the meantime, human decides in the context of knowledge from outside and inside knowledge inputs. Outside and inside contexts are used through human context because humans are authorized and responsible for predefined contexts. In Fig 6, letter C on arrows denotes contextual connection in the direction of arrow.

Term outside input context means human affects on an actual input request. A new element in this model is that results for product model wide coordination activities are allowed to consider by the human who is working on an actual task. This contributes to shorter product development cycle. Although authorized human is allowed to define completely independent request, considering some contexts such as legislation and standard is mandatory. These contexts are built into product model and work automatically. Customer demand is a quality assurance related context. Higher level decisions are made on higher levels of organizations. While valid, they act as mandatory contexts. They can be modified only by the decision making level. At the same time, human who is responsible for a relevant task may propose their modification. Although role of theoretical background sometimes is argued in the current industrial practice, organic presence is proposed in this model.

Inside input contexts are emerged and accepted within the scope of product related projects. Experience mainly consists of mistakes and fails and proven solutions from the past. Collecting of experience from the past decades is under consideration at leading companies in the industry. This is part of efforts to avoid repeated work on successes and repeat of fails in company engineering practices. Great values can be accumulated in product modeling environments in this way. Simulations and experiments are available for human as inside input contexts.

Human activities during definition of requests are mainly about parameterization of objects to be defined for a product. Although objects also can be defined, the aim of these activities is to prepare product object definition by the definition of specification and knowledge. Object selections, as well as function and quality selections for objects are included in the knowledge model.

Request results are explained by their contextual connections in Fig. 6. Objectives are defined in the context of quality specifications. Objects and methods are defined in the context of objectives. Methods represent knowledge composed mainly by mathematical functions and formulas, procedures, and rules. Any representation of knowledge and method is aimed to include in future product models. Outside sources are often linked considering license and other rights of knowledge owners and expertise holders.
is utilized at correction of model, establishing consistent model, validation of results, keeping threshold knowledge, and supporting repetitive tasks.

Because active knowledge is present in current industrial product modeling, the proposed modeling should be integrated into current product lifecycle information management systems. Implementation of the proposed modeling is possible as an application developed segment of full feature driven industrial product modeling systems where situation based control of product feature parameters is available.

V. CONCLUSIONS AND FUTURE WORK

As part of a research program by the authors of this paper to enhance knowledge based decision making and realize objective driven product modeling, this paper discusses situation based definition of product objects and outlines a method that can be fitted into the research program and allows for integration with state-of-art situation based methodologies in industrial product modeling systems.

According to the concept and approach by the authors, the proposed situation based modeling allows for taking all knowledge and specification entities into consideration at behavior based decision on product objects. Product objects and their parameters are controlled by actual set of circumstances for situation. Situation defines behavior covering a requested objective definition. By situation and its application, knowledge is introduced in engineering activities where human applies expertise at request definition while decides request in the context of knowledge from outside and inside inputs. Consequently, knowledge context is used through human context.

In the next future, entities should be conceptualized for the representation of behavior in the context of human request representation considering implementation in currently prevailing situation based product modeling systems with open software structure for application development. Other work is the flow of information from human request definition to adaptive control of product objects in order to support establishing an appropriate set of knowledge representation entities for industrial problem solving.

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REFERENCES