A Meta Model based Configuration Approach for mass-customizable Products and Services

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Abstract. We argue that extensibility is the key factor for domain independent mass customization solutions concerning product and service modelling and configuration. A modelling approach for hard- and soft-customizable products and services is introduced. To achieve extensibility a meta-model based strategy is chosen concerning modelling and implementation aspects. The meta model is based on a flexible and generic concept for modelling highly variable products and services of practically any domain. Such a meta model cannot only be understood as the basis for product modelling or configuration, but for the whole mass customization supply chain.

1 Introduction and Motivation

Mass Customization (MC) has been developed as a management strategy in the 1990s. By combining individuality of customized goods with adequate low prices as known from mass production, this concept has been considered to reach high customer's satisfaction. Thus, flexibility and low response times are conditions for the desired variety and customer orientation in businesses [Pine93] [Pill01].

As information management is a success factor in realizing MC business models, efficient systems using information technology are needed. Especially the section *configuration* as a main part of an MC order must be supported. All desires and individual characteristics which are relevant for creating the good have to be recorded and processed into a product or service specification. MC will have impact on business information systems by its specific requirements [DTKi03]. So, in this paper we focus on product modelling and we will introduce a meta-model based approach for the entire scope of MC.

Theoretically, there is no restriction in applying MC to either highly specialized or rather generic branches or goods. In order to distinguish different types of MC business models several classification models have been published. [Coat95] introduced hard customization and soft customization, at which the first type means a customization during manufacturing and the second type stands for customization before or after the manufacturing process. Other dimensions of differentiation are: type of good (product, service etc.), executor of the customization process (customer, manufacturer, retailer etc.), type of parameters (fixed values, discreet, stable, range, combination etc.), and point of customization (marketing, production, delivery etc.). In [Pill01] Coates' classification is extended to a six field model as shown in Figure 1.

Product modelling for MC must manage complex dependencies. Because of the necessity of limiting the range of customization, several individual components of a product must join other individual components as well as standard parts. So the major criteria for the development of the proposed methodology are extensibility and simplicity. Extensibility is needed in order to adapt the approach to horizontal as well as to vertical domains. Simplicity, on the other hand, supports usability within the usage of the methodology and guaranties clarity in order to realize simple communication and transmission of the created models.

Soft Customization	Hard Customization	
Self customization	Customization-Standardization-Mix	↓ Degree of customer specific activities of the value chain
Point-of-delivery customization	Modular product architectures	
Service customization	Flexible customization	

Figure 1 Characteristics of MC [Pill01]

The main target of this paper is to illustrate a methodology which can be used for all types of MC business models. A uniform structure throughout the whole business process will avoid media breaks and will enable efficient information exchange among all participants of the MC process. Therefore, a meta-model consisting of a method specific meta model and a domain specific meta model is introduced. In order to consider one of the particular requirements of suppliers in the field of mass customization, we establish a specific notation for representing product catalogue structures in information systems for mass customization.

2 Characteristic Aspects of the Meta-Model

The requirements, simplicity in the sense of usability and clarity, are the motivation for a visual approach consisting on the one side of a graphical notation of the part-whole-relationship based on [WeMü81] and on the other side of classification trees based on generalization hierarchies [HüLW02]. The basic modelling elements are: *Piece of Text* for final, not further decomposable parts, *Conjunctions* to express that several subparts are composed into a higher level part (this composition process can be done repeatedly) and *Alternatives* to express that an exclusive decision has to be made which subpart has to be chosen. To further extend the semantics of alternatives the *Empty Piece of Text* is introduced which allows the distinction between optional and mandatory alternatives. This enables us to express complex product or service models. But there are still two open issues: How to specify complex dependencies between alternatives and how to enable customization within specific ranges?

To efficiently restrict the domain of possible product variants specified by alternatives the concept of *Implications* is introduced. E.g. you can express that an eight cylinder engine implies an automatic gear box by using an Implication. This modelling construct leads to a reduction of complexity in our models and supports simplicity and clarity. Figure 2 gives an example of the benefit of Implications using an abstract use case that demands to choose the *Piece of Text* c, if a is chosen: both figures are equivalent with regard to the product family described, but the structure on the left is of lower complexity.

To enable different types of parameters we extend the Pieces of Text by typed attributes restricted by constraints. For example, we can express that the size of a sneaker can be specified in inches but that the real number describing the length must be between 1 and 20 inches. The meta-model is illustrated in Figure 3 based on a modelling approach specializing and extending the method specific ER-Model by domain specific extensions for mass customizable products [JaPM03]. The content of the domain specific meta model (DSM) expresses the concept of modelling products or services explained so far by deriving the necessary entities, relationships and attributes or constraints respectively.

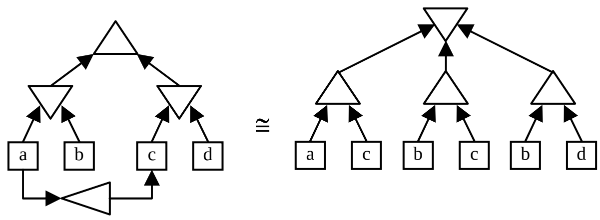

Figure 2 The Benefit of Implications

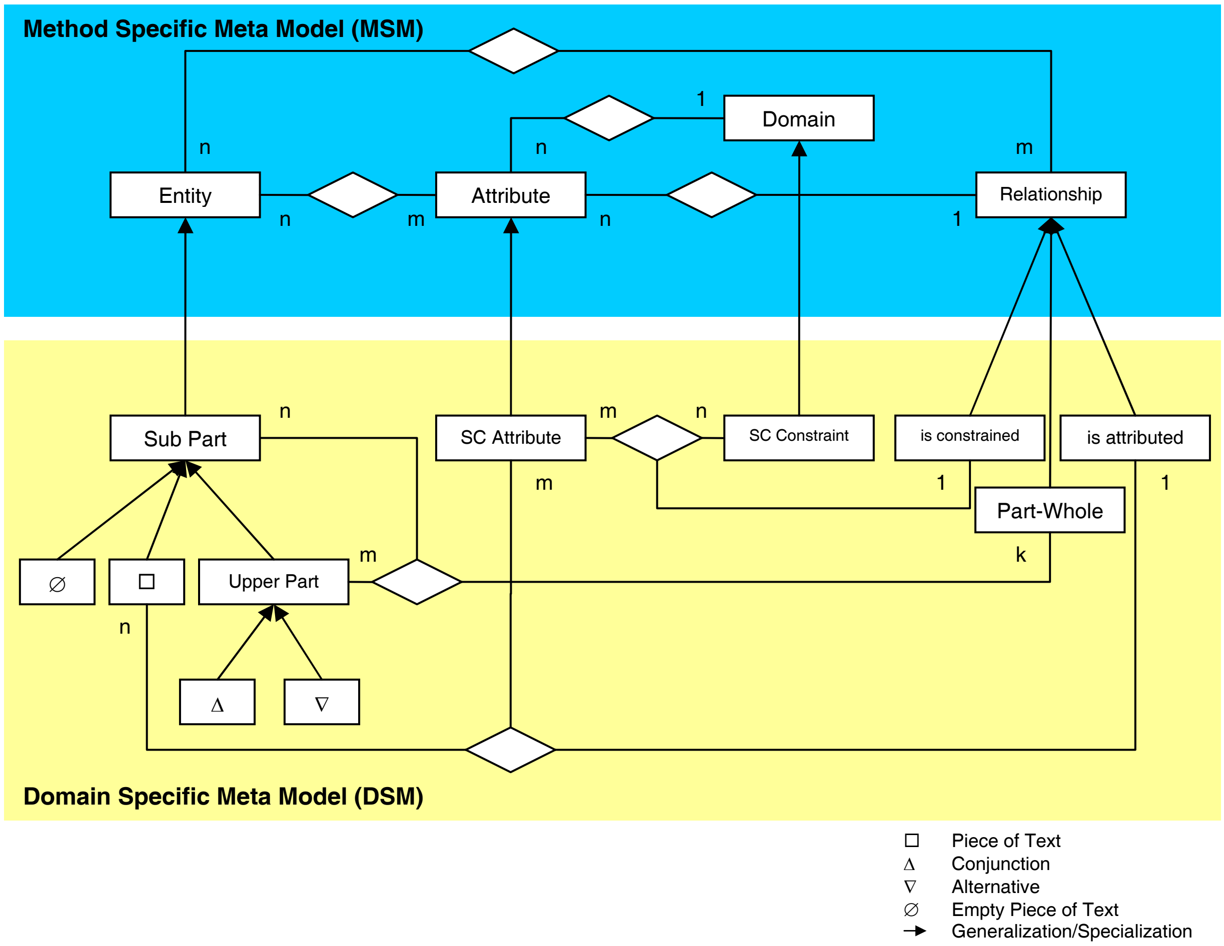

Figure 3 Meta model for mass-customizable products and services

The method specific meta model (MSM) defines the different types of meta modelling elements and their relationships, in the case of ER that is *Entity*, *Attribute*, *Domain* and *Relationship*. Please note that *Relationship* on that level is an entity. The DSM comes into existence by specializing the entities defined by the types. In Figure 3 the special relationship *Part-Whole* can be seen, which is connected with the special entities *Sub Part* and *Upper Part*. The constraints imposed by this method of modelling can be exploited by modelling tools and support the overall modelling process.

Our key requirement is extensibility of the whole model because it should be applicable to every application domain. For example, a supplier might often run into the situation depicted on the left side of Figure 4: the structure describes a product catalogue allowing to choose several products out of P_1 to P_n at the same time.

Instead of modelling this structure, a new and reusable modelling element "product catalogue" is introduced as can be seen on the right side of Figure 4 which is by far clearer for all participants.

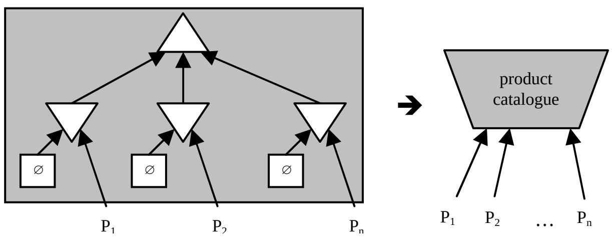

Figure 4 Introducing a new modelling element: product catalogue

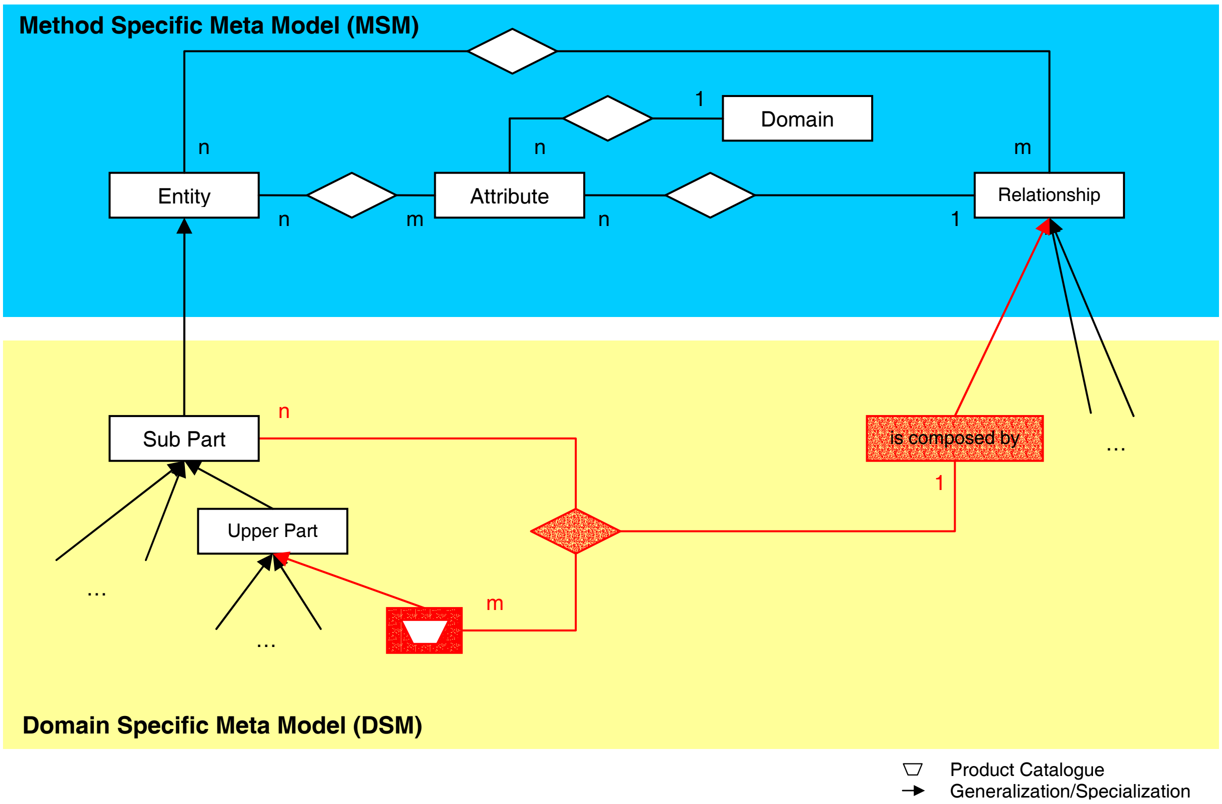

Figure 5 "Product Catalogue" on the Meta Model Level

By introducing new modelling elements on the meta level we further simplify the model (especially its clarity and compactness) by packaging a combination of existing modelling elements into new ones. This is done by aggregation on the meta level. The step of introducing the "product catalogue" is illustrated in Figure 5. The core meta model described before is extended by the modelling element "product catalogue". So far we have shown solutions to the field of extensibility on the model level. The next section combines this with implementation aspects.

3 Implementation Approach

Our meta-model based approach allows implementing a product configuration component in a flexible and extensible way based on the reification concept, especially on reflection and introspection. Reification can be shortly defined as "the ability of the program to access the metadata as regular data" [CzEi00]. This allows us to associate the code directly to specialized domain specific entities in the meta model (within DSM). This must be explained by several modelling elements from the meta model.

Let us assume we are in the middle of a product configuration process starting at the root of our product or service graph. The configuration tool reaches a modelling element. To decide what to do the reification concept is used and on the meta level we can determine that the current element is of type Alternative. The model also expresses that Alternatives have at least two sub parts of arbitrary types and the associated program code has to offer a dialogue to the user that enables him to choose exactly one of the sub parts.

A second example concerns the Product Catalogue introduced to our meta-model in the section before. At configuration time the new modelling element must be interpreted. And now the real advantage of our meta approach becomes clear: Independently from the fact that the configuration tool knows this modelling element it can retrieve its meaning by using reification. In case the tool has no special routine for visualizing Product Catalogues it can query the meta-model which results in the fact that Product Catalogue is an aggregation of well known and interpretable modelling elements. The interpretation can be done because of the fact that Product Catalogue consists is the Conjunction of several optional Alternatives over single product families. The code to be generated for this purpose is well known, because it is associated the basic modelling elements Conjunction, Alternative and Empty Piece of Text on the meta-level.

In a similar way typed parameters are supported. The configurator reaches an object that is identified as a Piece of Text using reification. This Piece of Text is associated with another object that can be identified as Attribute. This Attribute is again associated with another object that can be identified as Constraint. The configuration tool now knows by the code on the meta level that a dialogue has to be offered to the customer that allows the user to enter a value of the determined data type obeying the constraint.

These examples clarify the usefulness of our extensible meta model based architecture. New building blocks can easily be introduced by aggregation on the meta level. By using reification this does not affect existing product configuration tools as long as they are acquainted to the meta model and they are strictly designed upon the reification concepts. Conventional configuration tools only based on a basic product or service model are not able to handle model extensions without changes to their implementation.

4 Related Work

In the context of MC, work related to our approach has been published with keywords like product configuration product modelling. Wüpping illustrates product configuration as a main part in realizing MC. Different types of configuration methods (rules-based approach, knowledge based approach), organizational and technical aspects of implementation are shown [Wüpp00, Wüpp01]. Hahn proposes a common model for product information (e.g. product catalogue) and configuration rules by using decision trees [Hahn03]. Hvam et al. present a procedure for building product models. For product analysis and object oriented analysis as two phases of the procedure trees and UML class diagrams are used [HRMH02]. A General model of product families is illustrated in [Ying02]. Model-based configuration is described as a combination of product modelling and solving a configuration problem. [WMKl03] introduce a meta-model for object oriented product modelling. This model has been developing for banking industry in order to describe financial products. It consists of the product meta model and the product model itself. A conceptual configuration model is described in [FFJa2001]. Because of the increase of product and process complexity the need for effective knowledge acquisition enforces more and more. For modelling configuration knowledge bases UML is used as it is a approved standard design language.

In comparison to the publications mentioned above, our approach addresses all types of mass customization. Up to now, modular product architectures are mostly supported, whereas service customization and self customization are unconsidered. The proposed methodology is furthermore related to variant bills of materials as known from production management.

5 Conclusion

In this paper we introduce a meta model based approach for mass customizable products and services especially addressing the configuration problem. By using the extensible meta model our approach can serve in arbitrary application domains. The application of the reification concept allows to extend the set of modelling elements at runtime without changing the implementation of the configurator.
Another benefit of our approach is that our uniform product and service model cannot only be used for configuration tasks, but even as the fundamental structure of the complete supply chain process. Here the advantage of introducing new modelling elements at run time is even more useful.
The modelling approach presented here is part of a larger eBusiness platform called Marrakesch [Marr03]. This platform focuses on matching highly configurable demands and supplies. At the moment the possibilities of using Marrakesch for MC is under investigation.

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