A Documentation Method for Describing Product Variability in Product Development of Two Case Companies

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Abstract

An important industrial trend today is the increasing use of mass customisation, which can be realised with product families. When a company is developing product families, the amount of product information is large. There are several users and different needs for product variability information. Finding the right information on product variability is not easy. There is a need for documentation method for describing product variability. The goal of this research is to define documentation method, which will give the sufficient information on product variability. The defined documentation method documents the variability in a systematic and standard way. It is a structural representation realized by features. The documentation method was considered a feasible method in the case companies. Product development specialists felt that it was understandable and easy to create and maintain. However, the objective of this method is not automatically transfer the variability information to the product configurator. It has to be seen as a support tool for product designers.

Keywords

Documentation method, product development, product family, product variability.

1 Introduction

An important industrial trend today is the increasing use of *mass customisation*, which is defined as the mass production of individually customised products and services. It will meet each customer's individual wants and needs exactly, but at prices comparable to those of standard mass-produced goods [Pine, 1993]. Mass customisation can be realised by product families. A *product family* is defined as a large set of end products (variants) constructed from a smaller set of components within defined product architecture [Erens, 1996]. A product family can be represented with a *generic product structure*, where all the components of the different variants are represented in one structure [Erens, 1996]. This structure can also be called as *product family structure.* Product families can have a modular product structure [Erixon, 1998]. Services have become a significant part of the economy. The most successful service providers have developed a set of standardised service components that can be mixed and matched at the point or time of delivery by satisfying customer needs [Meyer and DeTore, 1999].

When a company is developing product families, the amount of product information is large. There are several users and different needs for product variability information. Product development specialists design the parts and modules, and they need information on the other

parts, such as relationships and constraints. Usually there are several independent design groups to design the parts or modules of a product, for example the motor development group designs all the motors for different vehicle product families. Development specialists understand the products at a very detailed level, whereas the sales department needs information on product functionalities and prices.

Typically, there are many different processes and ways of working to create and manage the product information in a single company. Typical methods for managing product information are different kinds of product specifications, which are usually text documents. These documents are usually saved in local directories or in databases, and the context of these documents is not standardized. Finding the right information on product variability from these documents is not easy, and the change management of the documents is not organized. If the company uses a product configurator, there is need for product variability information, which can be generated into the configuration model. The product development personnel know the product and its features very well, but usually are not very good at programming product rules into the product configurator.

There is a need for documentation method for describing product variability in the product development phase. The goal of this research is to ***define documentation method, which will give sufficient information on product variability to product information users and for example configuration model creation***. The document should be easy to create and maintain, so that there is no need for special education for understanding the document.

There are several semi-formal or formal product specification methods available [e.g. Erens, 1996; Haug & Hvam, 2006; Sivard, 2000; Dong, 2001], and defined documentation method is based on the previous knowledge on product family structuring.

2 Research Methods

This research was performed in two case companies. Both of the companies had challenges on documenting product variability. They needed an overall documentation on the product and its features, which will offer product variability related information to other designers and people from other departments (company 1) and to serve as an input for configuration model for their product configurator (company 2).

Qualitative research methods were used [Patton, 1990]. First, a literature study was performed to understand the previous work in this area. In the case companies the research was applied by using design research [March & Smith, 1995] and action research [Baskerville & Myers, 2004] methods together. An initial documentation method was developed with the case company 1 in 2002-2003 and it was improved with the company 2 in 2004-2005.

Collaborative development was performed with experts from product development and IT departments. We interviewed experts during project meetings, and studied existing documents on product data management and related IT systems. Existing processes, practices and systems on product data management were analysed, with special emphasis on methods for managing product families. To ensure that all the relevant data was considered, we recorded the interviews and discussions, and collected the necessary documented product data. Afterwards, we listened to the recordings and took notes of relevant information. We analysed the gathered data and identified practical requirements on the documentation method. Based on this, we designed a documentation method that can capture the variability encountered in case product families.

2.1 Case Company 1

Company 1 is a part of the global engineering and technology corporation and is a leading supplier of equipment, service and process solutions to industries including quarrying and aggregates production, mining and minerals processing and construction and civil engineering. Net sales was about 2 ME and number of employees was 8 500 in 2005.

In this study, one product family group was examined. The product family group consists of several product families with many variants. For example, one product family consists of 87 different variants. Products are engineer-to-order products and customer can select different functionality for a product depending on the usage. Delivery time for the product is about 5-8 weeks. Product families consist of modules and parts and one module or part can be included into many product families.

During the present state study, following challenges were identified; product development for product families was missing; they only have customer projects, where the customer orders were designed. Terminology was different in different projects and the product family structures were described differently in different projects. Variability for the customer was not visible in the product structure. Amount of the product variants was quite large and there is a need to reduce the variants. Not all these variants brought any new functionality to a customer. The goal was speed up the delivery from 5 to 2 weeks. There was also need to clarify the product policy by determining the functionalities, which will be offered to the customers. There was also a need for standardised product family structure definition and template for product variability, where the product features are well available. This also requires a common terminology definition for all product families and product projects. The amount of the changes into the design in the product development phase is large and product variability documentation changes often. That is why the changes into documents should be easy to make. In addition, documentation method should give sufficient information on the variability to all who needs it, e.g. marketing and sales departments.

2.2 Case Company 2

Company 2 is a telecommunication company and it operates in Europe. Net sales of the company 2 was about 10 ME in 2006 and number of employees was over 25 000.

Company 2 offers telecommunication service products. This work concentrated on mobile subscriptions to consumers. Structurally the products were very similar - almost the same set of services was available in all products. Further, mobile subscriptions were quite easy to configure, because there were relatively few constraints between service elements or their functionalities. Mutually alternative service elements were relatively common (e.g. at most one data service at a time). Some service elements were included by default in a product, some must be explicitly selected, some are always included and some are not available in a product. Pricing is a major differentiating factor between product families and there are several different sales channels for ordering services.

Internal product specifications were incomplete and not very systematic. The structure of the specifications was varying and variability information scattered around several documents. Some variability information was not described at all in the specification documents; these were available only on the product website. It was a difficulty to get a comprehensive view of variability and constraints in the specification documents. Terminology of variability was not

standardised. There was many terms used in describing the same issue (e.g. property, feature, component, element …) but there were no commonly accepted definitions.

The goal was to define systematic and standard way to document variability. Complete information on product variability was needed to enable configurator developers to create the configuration model based on the documentation, or at least to minimise iteration and need for clarifying questions from the product development. It was required that the documentation method should be simple to create and maintain, and easy to understand. It was desired that representation and terminology should be independent of any specific information system.

3 Previous Work

Many different methods for describing product families are available. All components of the different variants are represented in one structure. Components in the generic product structure can be common, alternative or optional. Alternative and optional parts are equipped with configuration rules. Configuration rules define what to include in a product. Variants are represented as instances that are generated from the generic product structure.

Erens [1996] has defined Generic Product Structure (GPS), which describes product families with traditional product structures. He recognizes two types of product structuring concepts: primitive generic products and compound generic products. Primitive generic product cannot be further decomposed into generic products. Compound product is composed of primitive generic products or other compound products. The product families are described with a specification, which consists of parameters and parameter values. GPS is a hierarchical structure and the elements in a structure can be either abstract or physical. Configuration constraints in the Generic Product Structure prohibit combinations of parameters. The configuration constraints can be expressed with the Boolean logic.

Hvam [Haug and Hvam, 2006] have developed the CPM-procedure, which includes a modelling technique for describing product families. This so-called Product Variant Master, PVM, consist of two sections; generic part-of-structure and generic kind-of-structure. The part of section describes the elements of which a product can consist and the kind-of-structure describes the possible variances of an element.

Sivard [2000] has shown how to represent the process of designing a product family using extended concepts of Axiomatic Design. She also has been described how the information acquired during this process could be used as a basis for building configuration models.

Dong [Dong et al., 2001] have created a Product Family Model, which describes a set of components (modules) with standardized interfaces and combination constraints. There could be common modules and selectable modules. The structure of the Product Family Model is represented in Generic Bill-of-Material (GBOM). GBOM is a tree, which consists of the nodes. The nodes are represented based on object-oriented technology. The node is an object and has the identification of a class, attributes, variables and constraints. Each node has constraints. Constraints can be classified into three classes; validity constraints, instance selection constraints and global constraints.

There are also several information systems in product development, which can support creation and management of product families. Usually product is designed in Computer Aided Design (CAD) system, where the part lists and the drawings (2D-CAD) or models (3D-CAD) are

created. Also Product Data Management (PDM) and Enterprise Resource Planning (ERP) systems can typically manage product family structures and its constraints. A PDM system usually allows management of generic product structures [Crnkovic, 2003].

A product configurator is an information system for modelling the knowledge in a configuration model and generating automatically or interactively product instances, configurations, that are valid with respect to the model [Sabin, 1998]. A configurable product is described with a configuration model. The task needed to produce a configuration is referred to as configuration task [Sabin, 1998].

4 Documentation Method Description

Based on the needs derived from the case companies, we have developed a documentation method for describing product variability in the product development phase. Documentation based on the method should give sufficient information on product variability to product information users. In addition, the documents should be easy to create and maintain, so that there is no need for special education for understanding the document.

The documentation method documents the variability of product in a systematic and standard way. It is a structural representation of variability realized by features. Because product families usually consist of different kinds of modules, which build up a product, and because modules may be used in several product families, the documents are divided into two kinds of documents; *Product Variability Specification* and *Module Specification*. An Excel template is provided for both types of specifications. The excel template was selected because it is familiar and available for all the employees.

4.1 Product Variability Specification

A *Product Variability Specification* describes the product variability on the module level. The following concepts for describing variability are used; *generic configuration rules, product specific configuration rules, features, pricing and sales channels*.

4.1.1 Generic Configuration Rules

The *generic configuration rules* are configuration rules, which span over all products. These configuration rules cannot be altered for any specific product. Typically, a configuration rule states that a certain feature requires or is incompatible with another feature (e.g. Service X is incompatible with Service Y, Service Y requires Service Z). Each generic configuration rule has a unique identifier (e.g. GR-1), which is used in the Feature-section to indicate that a certain feature is affected by the rule. The current set of applicable generic configuration rules are maintained in the latest version of the *Product Variability Specification Template*.

4.1.2 Product Specific Configuration Rules

The *product specific configuration rules* are only applicable to the product in consideration. Product specific configuration rules have unique identifiers (e.g. PR-1) so that they can also be referred to from the Feature-section.

4.1.3 Features

The Features-section describes how the shared services and their features are applied to the product in consideration. Features are arranged into levels. Non-top level features can only be selected to a configuration if the parent feature is selected to the configuration. If a feature is defined with a cardinality (e.g. select 0…1), then the number of features selected to the configuration from the following level must satisfy the cardinality.

Common cardinality definitions:

- (select 1) – requires that a single feature must be selected from the alternative features in the following level to configurations
- (select 0..1) – states that either zero or one feature must be selected from the alternative features in the following level to configurations
- (select n..m) – states that at least n, but at most m features must be selected from the possible features in the following level to configurations

Product specific services and features can also be defined and existing services can be modified. These alternations must be highlighted by setting "New or Modified Service Feature" to "Y". The current set of available services is maintained in latest version of the *Product Variability Specification Template*.

All subfeature levels of a feature are grouped using the grouping function of Excel (Menu → Data → Group and Outline → Group) so that subfeatures can be hidden. A feature with its subfeatures grouped can be seen in Figure 1.

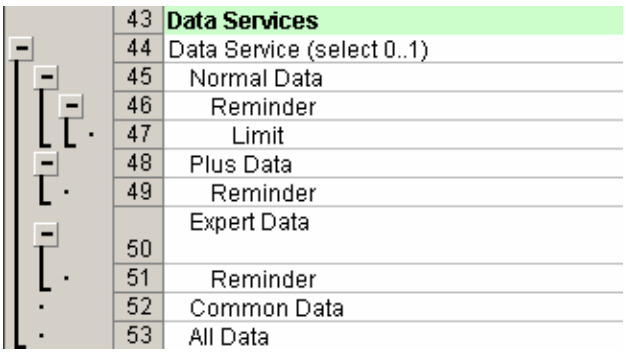

Figure 1: **Feature grouping.**

4.1.3.1 Availability

The valid possibilities of selecting features into a configuration are specified by *availability*. In addition, availability can specify default feature selections. The different availability classes are:

- Mandatory – always selected to a configuration, cannot be removed
- Included – optional, selected by default to a configuration, can be removed
- Available – optional, not selected by default to a configuration, can be selected
- Not available – not included in configurations, cannot be included

Feature availability is specified from a drop-down list (see Figure 2). If a feature's availability is "Mandatory" in the template, its availability must not be altered in a product specific specification. To support the development process, unknown availability can be specified by setting availability to "?".

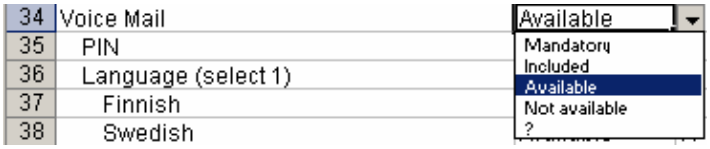

Figure 2: **Specifying feature availability.**

4.1.4 Pricing

Product prices (e.g. monthly charge, year charge) are defined in this section. Standard prices are shown with a grey background and these cannot be changed. However, if the standard price is not used, "Use Standard Price" must be set to "N" and the price must be specified. The Product prices section can be seen in Figure 3.

Figure 3: **Specifying product prices.**

The current standard prices are maintained in latest version of the *Product Variability Specification Template*.

Prices for features can be either product specific or based on the standard prices. If the standard prices are used, the price cells are shown with a grey background. If the standard prices are not used, "Tailored Feature Pricing" must be set to "Y" and the prices must be specified. The possible different prices for features:

- Usage – usage charge
- Monthly – monthly charge
- Connect/Disconnect – connection and disconnection charge

If it has not been decided yet whether standard prices are used, "Tailored Service Pricing" can be set to "?". The standard prices for features are not shown in *Product Variability Specifications*. The standard prices for shared features are maintained in the *Module Specifications*.

4.1.5 Sales Channels

Sales channels can be either product specific or based on the specific standard sales channels. If the standard sales channels are used, the channel cells are shown with a grey background. If the standard sales channels are not used "Tailored Service Order Channels" must be set to "Y" and the availability in each sales channel must be specified. If it has not been decided yet whether standard channels are used, "Tailored Service Order Channels" can be set to "?". The standard sales channels for features are not shown in *Product Variability Specifications*. The standard sales channels for shared features are maintained in the *Module Specifications*.

4.2 Module Specification

A *Module Specification* describes the features of a single module in detail. Default values for availability, pricing and channels of a feature are defined in module specifications. When feature default values are used in a *Product Variability Specification*, the values can be looked up from the services *Module Specification*. In the Features section, modules and their features are specified with their standard availability, pricing and channels. Default availability for top-level features is defined in the *Product Variability Template* and is set to empty in *Module Specifications*. Standard or different possible prices for features can be defined. Standard channel availability for feature can be defined.

4.3 Documentation Method Evaluation

The tentative evaluation of the defined documentation method was done in both companies. The participants in the co-operation project created the product variability specifications together with the researchers and the usability of the documentation method was discussed informally. The product variability specifications were also introduced to product information users from other departments.

The test users felt that the documentation method was understandable and documents were easy to create and maintain. They felt that the templates are simple, but still offer enough information on the product. They still felt that the deep knowledge of the product variability when creating the documents and good instructions of the use of documentation method are needed for ensuring correct specifications. In addition, the product variability users from other departments felt that it is easy to see the product variability from these specifications especially when comparing to earlier product specifications.

5 Discussions

The defined documentation method is based on the knowledge from previous work described in the Chapter 3. On the upper level the representation idea is the same; all components of the different variants are represented in one structure. Components in the generic product structure can be common, alternative or optional. Alternative and optional parts are equipped with configuration rules. Configuration rules define what to include in a product. We defined the method by simplifying and synthesizing the product variability description idea for fulfilling the requirements from the case companies.

The documentation method seemed to be feasible and sufficient tool for describing variability in case product families. It works well with the simple products and if the product variability is complex, the method still allows the sufficient description of the variability. In the case company

1, the first version of the documentation method was introduced. The first version defined the generic configuration rules, product specific configuration rules and features. Pricing and sales channels were introduced in the second version of the documentation method in the company 2.

Modelling of price was not needed in the company 1, and in our view pricing is not usually part of the variability definition. However, in some contexts modeling of price is very important. Different pricing models were probably the most important driver for product variability in company 2. Our price modeling mechanism is simple as it models only individual prices for individual features. It does not support more complex pricing models.

Our method supports iterative definition of the product variability descriptions. It is possible to represent product families where not all the parts or modules are defined yet. Unknown values can be explicitly specified (by setting "?" values). This communicates to other users that the functionality is not yet determined perfectly.

Documentation method is based on the requirements derived from the real companies providing real products to the customer. Participants from the case companies were highly skilled and motivated to develop product variability documentation method. They understood very well the environment around the research goal.

The documentation method does not have any tools for checking incorrect specifications. However, the objective of this method is not to automatically transfer the variability information to the product configurator. It has to be seen as a support tool for product designers. In addition, it needs to be deeper evaluated in the case companies and more tested in other companies with different products.

6 Conclusions

One important industrial trend is the increasing use of mass customisation, which can be realised with product families. When a company is developing product families, the amount of product information is large. There are several users and different needs for product variability information. Typically, there are many different processes and ways of working for creating and managing the product information in a single company. Finding the right information on product variability from these documents is not easy and change management of these documents is not organized. There is a need for documentation method for describing product variability in the product development phase.

The goal of this research was to define documentation method, which will give the sufficient information on product variability to product information users and for example configuration model creation. The document should be easy to create and maintain, so that there is no need for special education for understanding the document. The defined documentation method is based on the previous knowledge on product family structuring.

This research was performed by using qualitative research methods. First, a literature study was performed to understand the previous work in this area. In the case companies, the research was applied by using design research and action research methods together. The research was started with the case company 1 in 2002-2003 and documentation method was improved by working with the company 2 in 2004-2005.

The documentation method was considered a feasible method for describing product variability in the case companies. Product development specialists felt that it was understandable and easy to create and maintain.

The documentation method does not have support for checking incorrect specifications. The method is intended to provide support for product designers, and we do not aim to automatically transfer variability information to a product configurator. The method needs more empirical validation in case and other companies with different products.

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