Quality Product Derivation: 
A Case Study for Quality Control at Siemens

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Abstract: - From our experience with customers who deploy customized software products, we have learned that deriving products from shared software assets requires more than complying with quality standards like ISO9126. Additionally, developers must consider what we call the quality profile of the final product. A process that matches the quality profile of final product during product derivation helps provide and validate industrial software application solutions. This paper describes this matching concept and its application in a case study of the development of a product lifecycle reporting tool at a large organization. Also we propose a tool that could enhance quality control.

Key-Words: - Quality Product Derivation, Requirements Engineering, Non-Functional Requirements

1 Introduction
Developing any system, even one for a single customer, requires addressing the customer’s functional and non-functional requirements (Quality of Service). However, many developers lack a convenient way to address the non-functional requirements. Especially difficult is handling variability of non-functional requirement.

Our project addresses this shortcoming by considering derivation process of a product starting from the quality requirements of a customer. We base our research on quality standards like ISO9126 [12]. The International Organization for Standardization (ISO) classifies the Non-functional Requirements by building a Software Quality tree (Fig. 2). Additionally to referring to ISO9126 standards, we consider the different customer priorities relative to the industry domain to build the quality profile of the final product. The impact of Non Functional Requirements on Variants may vary [20]. We treat the variability from a functional and non-functional requirement (NFR) perspective [16] and [9] [10] to derive products.

The remainder of this article is organized as follows. The next section describes the state of the art. In Section 3, we describe our quality product derivation. Section 4 summarizes a case study that applied our approach. We propose an implementation of our approach as a quality control tool in Section 4 and conclude in Section 5.

2 State of the Art
Prior derivation approaches like Deestra’s approach [5] or like RED-PL approach [6] focuses on the decision-making process during product configuration. For example at some point in time a software customer must choose initial requirements, that involves selecting some and excluding some undesired requirements. We extend the work of Djebbi and Salinesi [6], [7] that considers also the product family. Quality profile and matching process is not found in current derivation approaches. The domain scope denotes the extent of the domain or domains in which the product family is applied, and consists of four levels of scope, i.e. single product family, program of product families, hierarchical product families [2] and product population [17]. The concept of domain knowledge for derivation is in accordance with the RED-PL approach [6] [7] and its corresponding CL language that uses both requirement attributes, and the domain of the attributes. Our approach considers NFRs as attributes [13]. We use the extended notation of [4], [8], [14], [15], [16] to get the NFRs representation. [1] [2] and [22] concentrate on implementation aspects of system variability and do not consider the non-functional requirements. Our approach differs from approaches in traditional models like Halmans and Pohl’s [11] that describe variability with use case diagrams and place dependences in a separate model. But like [11], we represent all variability types and cardinalities that are associated to variants [20].
3 Quality Product Derivation

3.1 Overview of Quality Product Derivation

Fig. 1 shows the four steps of the Quality Product Derivation: define the quality profile of final product, build the derived product using the matching process, realize the derived products and validate and test the derived products. In each step, we have to consider information about the quality requirements and the NFR impact on variants [19] [20]. Each step is iterative. The quality product derivation is the construction of a software product that is built by matching the selection of product family artifacts structure with the quality profile of the final product. We will focus in this paper on the first two steps.

3.2 Quality Profile of Final Product

The first step of the Quality Derivation Process defines the quality profile of the final product. This quality profile addresses different goals from the different customer points of view. Many important goals are "non-functional". They are not the same goals according to the sector they belong to. Most of the product families we encountered in practice have a profile that can be classified according to two dimensions of scope: quality and domain scope. The first dimension, quality scope, is arranged according to NFR classification based on ISO9126 (Fig. 2).

**Fig. 2: Software Quality according to ISO 9126**

It captures almost all common and different characteristics of the product family members (configurable product family). In addition to the quality scope, we identify a second dimension, the domain scope. The domain scope denotes the extent of the domains in which the product family is applied [2] [17]. We use the standard classification of economic activities published by the United Nations Statistics Division: International Standard Industrial Classification of All Economic Activities for studying the different qualities expectations according to the industry category they belong to. The Structure Level 1 is list of tabulation categories marked by one-letter alpha code- A to Q. For our research work, we will focus on the 4th till 11th category as shown in Table 1. Scalability is provided through all ISIC sub-sections.

**Table 1. ISIC Categories for Quality Product Derivation.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Letter Code</th>
<th>Industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>D</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>Electricity, gas and water supply</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>Construction</td>
</tr>
<tr>
<td>7</td>
<td>G</td>
<td>Wholesale and retail trade; repair of motorcycles and personal and household goods</td>
</tr>
<tr>
<td>8</td>
<td>H</td>
<td>Hotels, restaurants, tourism</td>
</tr>
<tr>
<td>9</td>
<td>I</td>
<td>Transport, storage and communications</td>
</tr>
<tr>
<td>10</td>
<td>J</td>
<td>Financial intermediation</td>
</tr>
<tr>
<td>11</td>
<td>K</td>
<td>Real estate, renting and business activities</td>
</tr>
</tbody>
</table>

According to our industrial research in the PLM field, we could find the following quality profile for final product: Automotive (G), Defense (sub category of I), Entertainment (sub category of H) and Manufacturing (D). The NFR can be quantified according to Chung’s satisficing values [4]: very satisfied (++), partly satisfied (+), neutral (0) or not determined (?), partly not (-) or absolutely not satisfied (--). For example the quality profile of final product for Automotive (G) concerning a PLM module could be: \(\text{QPP_{iso9126-ISIC-G}=Portability[PLM-module].++}\). It means the NFR goal of companies belonging to Automotive Industry (OEM suppliers) addresses in particular the portability which has high importance as the satisficing value expected is "very satisfied" (++).
3.3 Matching Process according to the Quality Profile of Final Product

In this step the derived product is going to be built according to the defined quality product profiles. The matching process consists in going through all the variant combinations found in the description basis of product line and select the combination matching the quality product profile of final product. The map model as quality product model provides the structure of variants according to their quality attributes. The variants analysis considers the quality profile of the final product to select some variants and delete others. Through the matching process one can obtain a variant structure among all variants combinations of the subset of shared product family assets. The final structure is the derived product.

Variants: As explained in [19], [20], we use the QVaM Quality Variation Model based on Map model [18] to represent Variants including NFR impact. Map is a process model expressed in a goal driven perspective. It provides a system representation based on a non-deterministic ordering of goals and strategies. The map is represented as a labeled directed graph with goals (Goal) as nodes and strategies (Strategy) as edges between goals and Section as way to achieve the target goal from the source goal. For example Strategy $S_i$ between the couple of goals $G_i$ and $G_j$ represents the way $G_j$ can be achieved once $G_i$ has been satisfied. Section $<G_i,G_j>$ represents a way to achieve the target goal $G_j$ from the source goal $G_i$ following the strategy $S$. A section named $ab$ designates a way to achieve a target goal $b$ from a source one $a$ following a strategy $i$. A variant [3] corresponds to a map section. For the NFR Impact on Variant, we refer to the ISO 9126. We have to first select NFRs. Then we have to quantify NFRs value in applying a value of impact of NFR [4] on variant/MAP section as explained in [19], [20]: this is the quality attribute of the variant. Fig. 3 shows that the impact of NFR Performance on Variant V is the value in sec. or min. or MB, etc. The impact of NFR Performance on Variant V concerning a PLM-module is written: $\text{QoS}(V)=\text{Performance}[\text{PLM-module}]$.++.

**Similarity metrics:** We adapt the deep semantic relations in the initial coefficients formula of Dice (Formula 2) to get the Modified Coefficient of Dice [21]. The formula (1) corresponds to the modified weighted Dice’s coefficient, where $A$ is the NFR impact on a variant (QoS,V) and $B$ is the quality profile of final product (QPP$_{ISO9126-ISIC}$). The coefficients $\alpha_i$ define the weight granted to the similarity between the different NFRs occurring in $A$ and $B$. The sum of coefficients $\alpha_i$ is equal 1.

\[ S_B^w(A,B) = \sum_{i,j} \alpha_i \times S_B(A_i,B_j) \]

(Formula 1) Weighted Modified Coefficient

Metrics defined by the modified coefficients of Dice are used for computing the measures explained hereafter. Similarity metrics are applied on $A$ and $B$.

The first metric is called TIS (Similarity Types of Intrinsic Factor and of Criteria Synonymy). The synonymy is a relation between $A$ and $B$ having properties whose names or values have a deep semantical similarity. We three different similarity degrees to evaluate if $A$ and $B$ are synonymous:

1. IDE metric when the value of $A$ is identical to the value of $B$, if they are expressed in the same terms and if they have exactly the same meaning, IDE($A,B$)=true if $S_{ID}(A,B)=1$.
2. SIM metric when the value of $A$ is alike or similar to the value of $B$, if these two values are identified with different terms but if they have the same meaning, SIM($A,B$)=true if $0.90 =< S_{SIM}(A,B) < 1$.
3. CLOSE metric: when the value of $A$ is close to the value of $B$ when these two values are expressed with different terms, but have close meaning, CLOSE($A,B$)=true if $0.80 =< S_{CLOSE}(A,B) < 0.90$.

The second metric is called TIIH (Types of similarity of Intrinsic Factor and of criteria Hyponymy/Hyperonymy). If $A$ and $B$ are linked by a relationship Is-A, they can be hyponymous or hyperonymous when the sense of one extends / includes the sense of the other one. The applied metric for hyponymy is HYPO. HYPO($A,B$)=true if $0.60 =< S_{HYPO}(A,B) < 0.80$. The applied metric for hyperonymy is HYPER. HYPER($A,B$)=true if $0.40 =< S_{HYPER}(A,B) < 0.60$.

\[ S_B^w(A,B) = \sum_{A} \text{MAX}[\text{SIM}(\text{Terms}_A,\text{Terms}_B)] + \sum_{B} \text{MAX}[\text{SIM}(\text{Terms}_A,\text{Terms}_B)] \]

(Formula 2) Modified Coefficient of Dice
4 Case Study and Quality Control Tool

4.1 Case Study
To validate our approach we conducted a case study at Siemens PL that extended a prior study [20]. It considers the reporting tool for Product Lifecycle Management. Fig. 4 represents the Functional Requirements that the system must fulfill to provide a data reporting tool for Product Lifecycle Management. On this PLM reporting tool, we have applied our approach of Quality Derivation for three different companies. This also considers the quality profile of final product and matching process. We define nine atomic variants. Fig. 4 is composed of 2 goals “Identify report” and “Conceptualize report” to create a report.

![Diagram of Functional Requirements of a PLM Data Report Tool](Image)

**NFR impact on Variants (QoS):** We used the Non-Functional Requirements Performance, Security and Informativeness whose decomposed subgoals are Time[ProduceReportStatement], Confirmation [PLMDataForReport] and SecurityWorkflowData [ProduceWorkflowReport] [20]. Table 2 lists the NFRs impact on atomic variants of Fig. 4.

<table>
<thead>
<tr>
<th>Name</th>
<th>Value of NFR Impact on Variants</th>
</tr>
</thead>
<tbody>
<tr>
<td>ab₁</td>
<td>ab₁, Time[ProduceReportStatement].+</td>
</tr>
<tr>
<td>ab₂</td>
<td>ab₂, Time[ProduceReportStatement].-</td>
</tr>
<tr>
<td>bb₁</td>
<td>bb₁, SecurityWorkflowData[ProdWorkflowData].-</td>
</tr>
<tr>
<td>bc₁</td>
<td>bc₁, SecurityWorkflowData[ProdWorkflowData].+</td>
</tr>
<tr>
<td>cc₁</td>
<td>cc₁, Confirmation[PLMDataForReport].-</td>
</tr>
<tr>
<td>cc₂</td>
<td>cc₂, Confirmation[PLMDataForReport].+</td>
</tr>
</tbody>
</table>

**Quality Profile of Final Product**

Table 3 shows the quality profile of final product of the reporting tool for three companies of different sectors: Defense, Entertainment and Manufacturing. ISIC Category D, F and I are in the domain scope.

<table>
<thead>
<tr>
<th>Defense</th>
<th>Entertainment</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLM Report</td>
<td>PLM Report</td>
<td>PLM Report</td>
</tr>
<tr>
<td>Efficiency.++</td>
<td>Efficiency.+</td>
<td>Efficiency.0</td>
</tr>
<tr>
<td>Informativeness.0</td>
<td>Informativeness.0</td>
<td>Informativeness.++</td>
</tr>
</tbody>
</table>

**Matching process**

According to the matching process, the similarity typologies and the metrics are performed with the formula of modified weighted DICE coefficient (Table 4).

<table>
<thead>
<tr>
<th>Variants</th>
<th>Results of Matching Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>ab₁</td>
<td>True</td>
</tr>
<tr>
<td>ab₂</td>
<td>False</td>
</tr>
<tr>
<td>bb₁</td>
<td>False</td>
</tr>
<tr>
<td>bc₁</td>
<td>True</td>
</tr>
<tr>
<td>bc₂</td>
<td>True</td>
</tr>
<tr>
<td>cc₁</td>
<td>False</td>
</tr>
<tr>
<td>cc₂</td>
<td>False</td>
</tr>
<tr>
<td>cd₁</td>
<td>True</td>
</tr>
</tbody>
</table>

Fig. 5 shows the results of derived variant/product. Applying our approach, we obtained preliminary design views for the reporting tool that were implemented in the resulting reporting system. By their positive responses, leaders who participated in this case study suggested our approach is worthwhile for wining billable projects. The derived product according to the profile 1 (Defense): ab₁ has been accepted, ab₂, cc₁, cc₂ have been denied. We follow the same way to get the derived product according to the product classification profile 2 (Manufacturing) and profile 3 (Entertainment). For confidentiality reason, we have not been authorized to publish detailed results from the case study. We can say participants were interested in having a quality product derivation way to derive the reporting product for customers with different application domains and priorities.
4.2 Quality Control Tool

We have implemented our approach as Quality Control tool in Teamcenter. Fig. 6 and Fig. 7 show the results of PLM data model extension for the new class NFR and the new relation “Satisficing Link” on variants in Teamcenter.

Fig. 6: SecurityWorkflowReport[ProduceWorkflowReport]

Fig. 7: Representation of Variant and NFR Impact on Variant

Fig. 8 shows the implementation of ISO9126 and quality profile of final product for Automotive ISIC G, defense (sub cat. J), Entertainment (sub c. of H).

Fig. 8: ISO9126 and Quality Profile of Final Product

Matching Process

A new workflow “Match-ISO9126-Compliance-ISIC-K” has been created (Fig. 9) to apply the formula of modified weighted DICE coefficient.

Fig. 9: Process “Match-ISO9126-Compliance-ISIC”

If the WF returns ok, the variant is referenced in the class view: ISIC-Derived Product (Fig. 10).
4 Conclusion

This paper proposes a Quality Product Derivation using a matching process on the quality profile of final product and NFR impact on variants. To identify the impact of non-functional requirements on variants, we represent the non-functional requirements by goals. We capture the variability through a goal-driven modeling formalism called map. In our Quality Derivation approach, we investigate how the NFR impact on Variants has to be considered in the whole quality product derivation process. To illustrate, we report a case study concerning a Product Lifecycle Management (PLM) reporting tool and we validate our approach in implementing a first version of ISO9126 quality control solution in the PLM software Teamcenter.

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References: