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Software and systems engineering — Methods and tools for variability traceability in software and systems product line

Ingénierie des systèmes et du logiciel — Méthodes et outils pour modéliser la traçabilité dans les gammes de produits des logiciels et systèmes

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 7, *Software and systems engineering*.

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Introduction

Software and Systems Product Line (SSPL) engineering and management creates, exploits and manages a common platform to develop a family of products (e.g. software products, systems architectures) at lower cost, reduced time to market and with better quality. As a result, it has gained increasing global attention since the 1990s.

Variability, which differentiates a member product from other products within a product line, plays an important role in SSPL; and hundreds of variabilities are introduced throughout the whole SSPL domain engineering stages. Those variabilities are defined, refined, newly added as domain engineering stages go forward. Variabilities thus are modelled carefully so as to manage and control them in a systematic way. This document deals with methods and tools capability for supporting variability modelling using consistent notations and for managing and/or utilizing variability models in domain and application engineering lifecycle processes.

This document can be used in the following modes:

— by the users of this document: to benefit people who want to adopt SSPL for producing their products by guiding how to model variabilities among member products;

— by a product line organization: to provide guidance in the evaluation and selection for methods and tools for variability modelling;

— by providers of tools and methods: to provide guidance in implementing or developing methods and tools by providing a comprehensive set of methods and tools capabilities for supporting variability modelling.

The ISO/IEC 26550 family of standards addresses both engineering and management processes and capabilities of methods and tools in terms of the key characteristics of product line development. This document provides processes and capabilities of methods and tools for variability modelling in product lines. Other ISO/IEC 26550 family of standards are as follows:

— processes and capabilities of methods and tools for domain requirements engineering and application requirements engineering are provided in ISO/IEC 26551;

— processes and capabilities of methods and tools for domain design and application design are provided in ISO/IEC 26552;

— processes and capabilities of methods and tools for domain realization and application realization are provided in ISO/IEC 26553;

— processes and capabilities of methods and tools for domain testing and application testing are provided in ISO/IEC 26554;

— processes and capabilities of methods and tools for technical management are provided in ISO/IEC 26555;

— processes and capabilities of methods and tools for organizational management are provided in ISO/IEC 26556;

— processes and capabilities of methods and tools for variability mechanisms are provided in ISO/IEC 26557;

— processes and capabilities of methods and tools for variability traceability are provided in ISO/IEC 26559;

— processes and capabilities of methods and tools for product management are provided in ISO/IEC 26560;

— processes and capabilities of methods and tools for technical probe are provided in ISO/IEC 26561;

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— processes and capabilities of methods and tools for transition management are provided in ISO/IEC 26562;

— processes and capabilities of methods and tools for configuration management of asset are provided in ISO/IEC 26563;

— others (ISO/IEC 26564 to ISO/IEC 26599): to be developed.

ISO/IEC 26550, ISO/IEC 26551 and ISO/IEC 26555 are published. ISO/IEC 26557 and ISO/IEC 26559 are to be published. ISO/IEC 26552, ISO/IEC 26553, ISO/IEC 26554, ISO/IEC 26556, ISO/IEC 26560, ISO/IEC 26561, ISO/IEC 26562, ISO/IEC 26563 are planned International Standards.

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Software and systems engineering — Methods and tools for variability traceability in software and systems product line

1 Scope

This document, within the context of the tools and methods of variability traceability for software and system product lines:

— provides the terms and definitions specific to variability traceability for software and systems product lines;

— defines process groups and their processes for establishing and managing variability traceability at product line lifecycle processes. Those processes are described in terms of purpose, inputs, tasks, and outcomes;

— defines method capabilities to support the defined tasks of each process;

— defines tool capabilities to automate/semi-automate tasks or defined method capabilities.

This document does not concern processes and capabilities of tools and methods for a single system but rather deals with those for a family of products.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
aspect
special consideration within product line engineering process groups and tasks to which we can associate specialized methods and tools

3.2
instantiated trace link
trace link (3.6) derived by applying binding in a member product

3.3
texture
architectural texture
collection of common development rules and constraints for realising the applications of a product line

3.4
traceability
discernible association among two or more logical entities, such as requirements, system elements, verifications, or tasks

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3.5
traceability with different abstraction level
level of detail for established *traceability* (3.4)

EXAMPLE The finer level of detail, the more general level.

3.6
trace link
association between two trace artefacts or between an element of variability model and a development artefact

3.7
trace link semantics
purpose or meaning of the *trace link* (3.6), specified in the trace link types

EXAMPLE 'Implements', 'refines', 'requires' and 'excludes'.

3.8
variability traceability
traceability (3.4) among variability definition, variability implementation in domain engineering and application engineering, and thereafter tracing impacts due to variability changes

3.9
variant
instance or value of a *variation point* (3.10)

3.10
variation point
indication of product differentiation based on particular variable characteristics of products, domain assets, and application assets in the context of a product line

4 Abbreviated terms

CRUD create, read, update, delete

OVM orthogonal variability model

SSPL software and systems product line

5 Reference model for variability traceability in software and systems product line

5.1 Overview

Variability is a key differentiator between single-system engineering and management and product line engineering and management. Product line engineering and management has to take explicitly into account the variations within and between multiple products. The product line variabilities are introduced and defined during product management, domain engineering and application engineering processes defined in ISO/IEC 26550. Explicitly defined variability is represented or implemented by different development artifacts, and it should be traced for the proper management. Variability traceability enables tracing variabilities defined in variability models from their introduction stage to binding stage. Variability tracing should be able to trace variability with all of relevant development artefacts of domain engineering and application engineering processes of ISO/IEC 26550.

SSPL traceability provides a set of linkages of artefacts in a product line. Compared to the traceability of single product development, SSPL traceability is more complex because SSPL has two separate but intimately related development processes, i.e. domain engineering and application engineering. SSPL traceability includes trace links between artefacts within the same stages, trace links between

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artefacts produced in different stages, trace links between domain and application artefacts, and trace links among variability-related artefacts. This document deals with trace links among variability-related artefacts, i.e. variability traceability.

Variability traceability enables the establishment and maintenance of trace links among variabilities described in the various forms of domain assets, application assets, and variability models. Variability traceability is important for the consistent maintenance and evolution of variabilities implemented/described in those various forms. Trace links can be simple relationships between different variability-related artefacts or they can be comprehensive and sophisticated trace information including trace link semantics. Because having too much (comprehensive) or too little (simple) traceability is costly or insufficient, an economic analysis for the abstraction level of traceability should be conducted in order to make decision on the appropriate level of details for traceability establishment and management.

The variability of a product line is spread all over development artefacts, so it is difficult to trace variability, for example, between the sources of variability and the corresponding artefacts. An orthogonal variability model (OVM), a separated model defining the variability of a product line, provides a cross-sectional view of the variability across all development artefacts. It relates the elements of a variability defined to different development artefacts such as feature models, requirements artefacts, architecture, detailed designs, codes, test artefacts, and after compile time artefacts (e.g. makefile). Thus, the variability of different development artefacts can be traced through an OVM. Figure 1 illustrates the concept of OVM-based variability traceability in domain engineering.

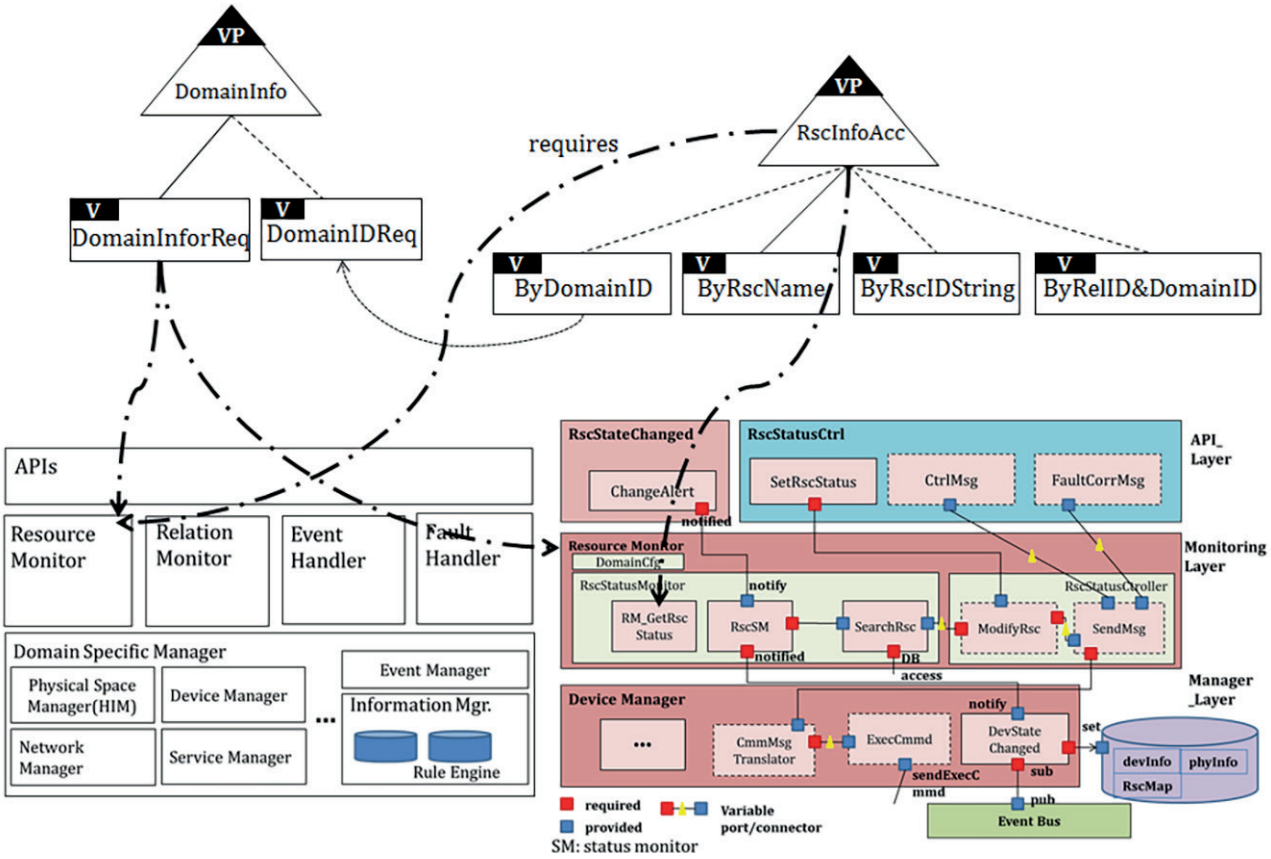

Figure 1 — OVM-based variability tracing in domain engineering

Variability relating to several domain development artefacts can be traced through the OVM. As shown in Figure 1, a variation point or variant can relate to different development artefacts of different stages. They can relate to a use case, corresponding sub-systems, and corresponding components. Therefore, relations among artefacts corresponding to the same variability either located in the same stage or different stages can be traced through the links from the elements of the OVM. Because the trace links from the OVM to development artefacts include links from a variation point to its representing artefacts

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and links from the variants to their realizing artefacts, impacts on the corresponding artefacts due to the variability changes or evolution can be completely and easily analysed.

The OVM, namely the domain variability model, relates with the application variability model in accordance with binding decisions and the corresponding trace links are also instantiated along with binding. Member product specific variability is defined through the application variability model and it relates to the corresponding application artefacts. From introduction time through binding time, variability traceability is achieved through the instantiated trace links, trace links between the OVM and application variability model, and member product specifically established trace links. Figure 2 illustrates OVM based variability tracing in a product line.

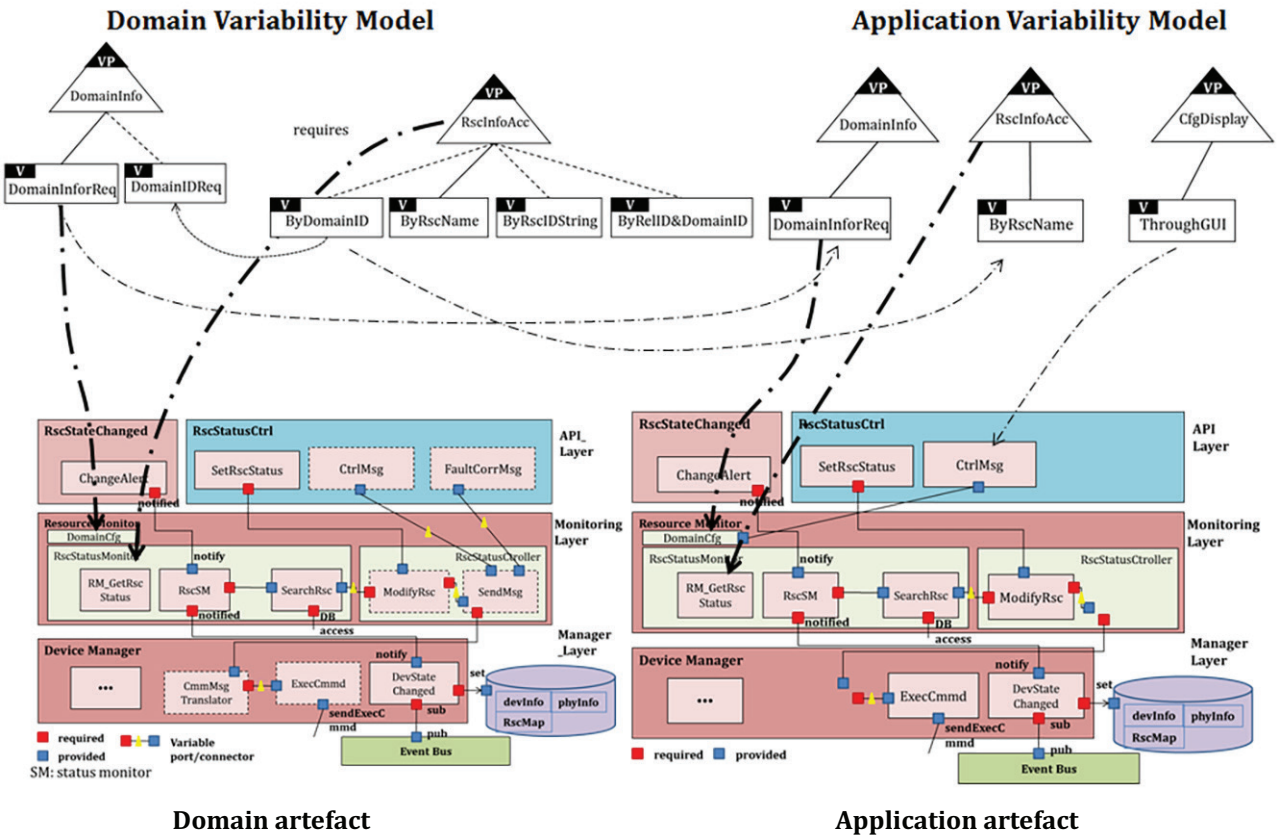

Figure 2 — OVM based variability tracing within a product line

The thick broken line means instantiated trace links in accordance with binding decisions in application engineering. There exists a newly added variability (e.g. CfgDisplay in Figure 2) and its trace link with application artefacts is defined.

5.2 Reference model for variability traceability in software and systems product line

The reference model specifies the structure of supporting processes and subprocesses for variability traceability in product line. As shown in Figure 3, variability traceability in product line can be structured into three processes: variability tracing management, variability tracing and variability tracing support. In the rest of this document, tasks, methods and tools are described in terms of processes and subprocesses defined in the reference model.

Each process is divided into subprocesses and each subprocess is described in terms of the following attributes:

— the title of the subprocess;

— the purpose of the subprocess;

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— the inputs to produce the outcomes;

— the tasks to achieve the outcomes;

— the outcomes of the subprocess;

— the capabilities of tools and methods are a list of the required support of tools and methods for performing the tasks properly.

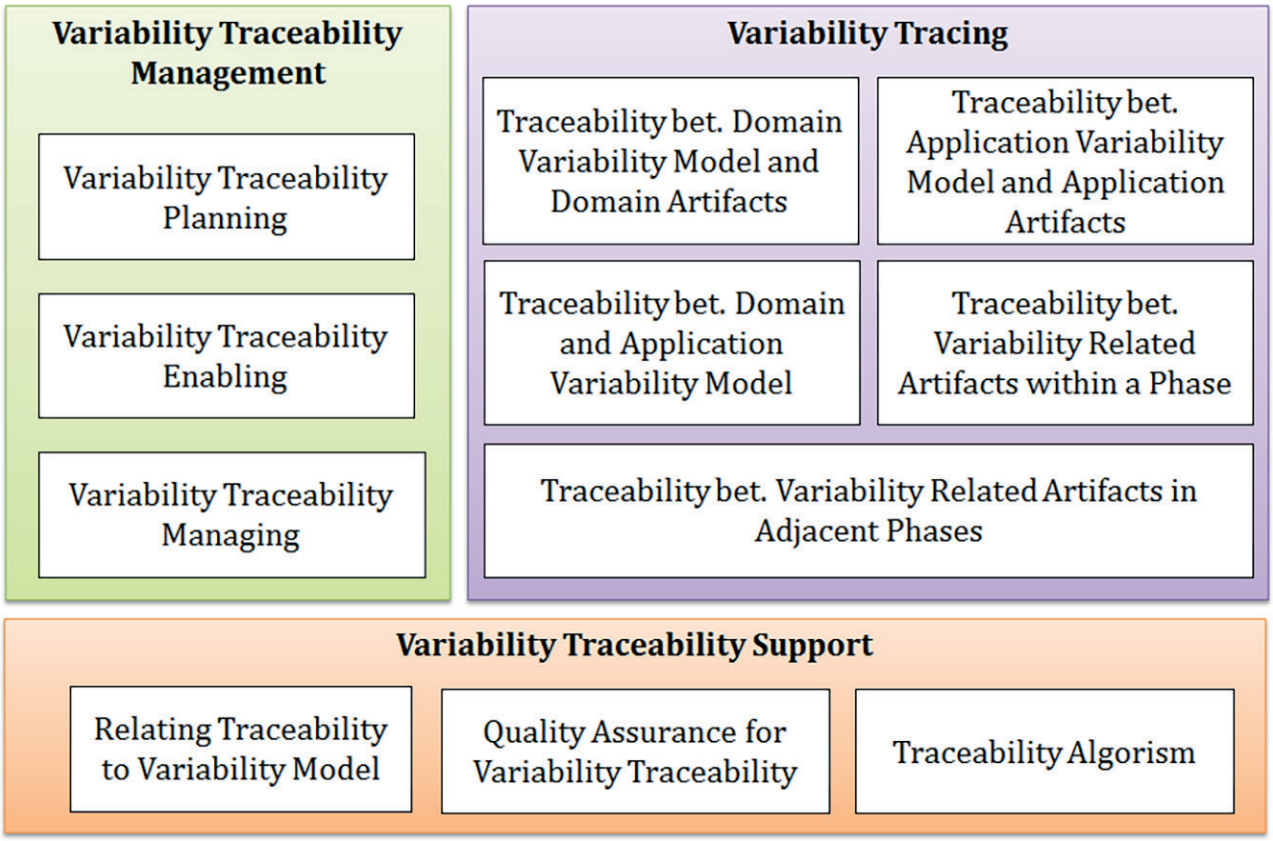

Figure 3 — Variability traceability in SSPL

The variability tracing management process supports for establishing plans for establishing and maintaining variability traceability with the different levels of detail, for providing enabling environments for realizing the planned variability traceability, and for managing plans versus actual variability traceability status. The variability tracing management process provides required principles and foundations such as the level of abstraction of traceability, traceability notation, and traceability algorithm for establishing and maintaining variability traceability. Variability tracing management shall do the following:

— variability tracing planning;

— variability tracing enabling;

— variability tracing managing.

The variability tracing process supports establishing and maintaining variability traceability in domain engineering and application engineering. Variability tracing shall do the following:

— traceability between domain variability model and domain artefacts;

— traceability between application variability model and application artefacts;

— traceability between domain and application variability model;

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— traceability between variability related artefacts within a stage;

— traceability between variability related artefacts in different adjacent stages.

The variability tracing support process provides required support for establishing and maintaining the required variability traceability including traceability algorism, validation and verification supports for established variability traceability, and traceability with variability models. Variability tracing support shall do the following:

— relating traceability to variability model;

— quality assurance for variability tracing;

— traceability algorism.

The identification and analysis of the key differentiators between single-system engineering and management and product line engineering and management can help organizations to understand the product line and to formulate a strategy for successful implementation of product line engineering and management. The key aspects have been defined in ISO/IEC 26550 and Table 1 shows the categories of the key aspects.

Table 1 — Key aspects for identifying product line-specific variability traceability tasks

Category	Aspects
Reuse management	Application engineering, domain assets, domain engineering, product management, platform, reusability
Variability management	Binding, variability
Complexity management	Collaboration, configuration, enabling technology support, reference architecture, texture, traceability
Quality management	Measurement and tracking, cross functional verification and validation

The following are the descriptions for each aspect concerning variability traceability for product lines. The variability tracing relevant processes and tasks shall be identified on the basis of these aspects. The concerns specific to variability traceability for product lines will enable an organization to understand the variability tracing relevant processes, subprocesses, tasks, methods and tools' capabilities.

— Application engineering: Variabilities-bound and newly-added application specific variabilities during application engineering should be traced. Application variability model plays a key role for maintaining those traceabilities.

— Binding: Binding results (i.e. variants decision) in a member product should be properly traced so as to manage them with variability changes and evolutions.

— Collaboration: Variability traceability enables collaboration among domain and application engineers.

— Configuration: Bound variability of a configuration should be traced and its version should be properly managed.

— Domain asset: Variabilities implemented through domain assets should be traced. Variability model is used to trace them.

— Domain engineering: Variability defined and implemented during domain engineering should be traced. Trace links for a variability implemented in different domain assets and trace links for a variability implemented throughout the different domain engineering stages should be established and maintained. Domain variability model can be used to trace a variability implemented throughout the different domain engineering stages.

— Enabling technology support: Technologies for establishing and maintaining trace links for variabilities should be supported.

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