Validation of the Conceptual Model for Unifying Variability in Space and Time

1 UNIFIED CONCEPTUAL MODEL

The unified conceptual model (Figure 1) describes essential concepts for modeling variability of a software system in space (variants) and time (revisions). It follows an open-world assumption (descriptive) instead of a closed-world assumption (prescriptive).

In Table 1, we provide a definition of the involved concepts.

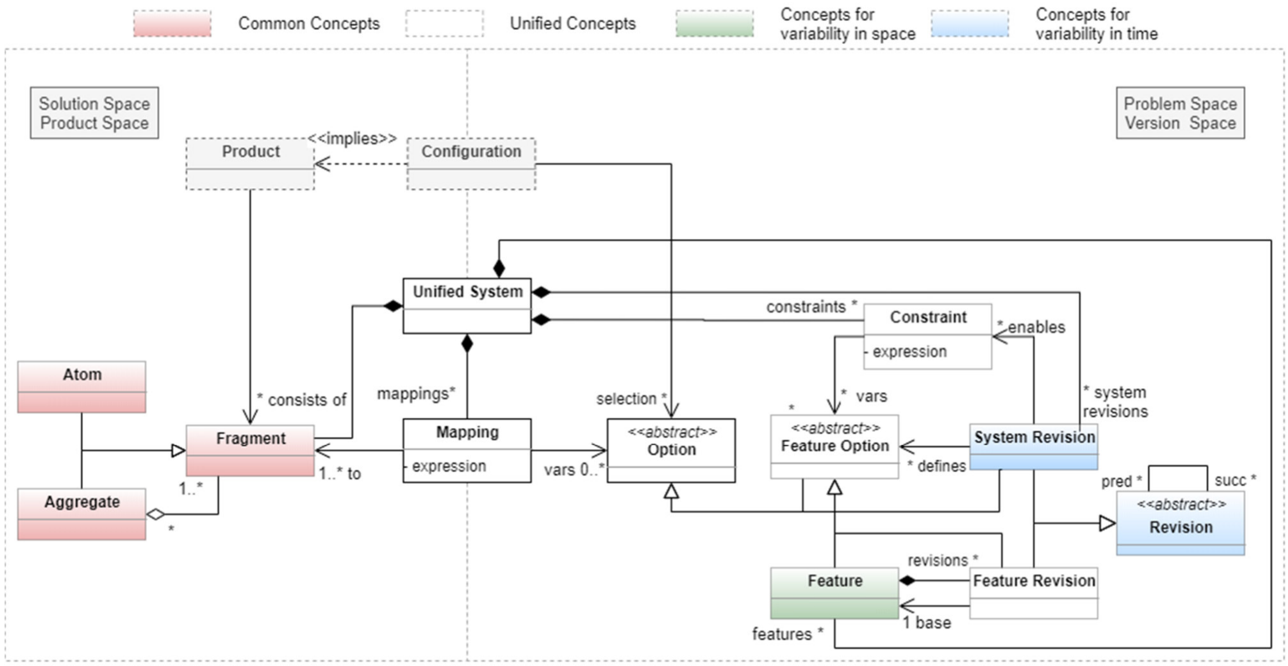

Figure 1: The Conceptual Model with common and unified Concepts for Variability in Space and Time.

Table 1: Definition of concepts in the Conceptual Model.

Concept	**Relation to other Concepts**	**Definition**
Fragment	*Product, Unified System, Mapping*	*Fragments* are the essential concept to describe a system on implementation level. A *Fragment* can either be an atom or an aggregate, e.g. a single file, character or the node of an AST. We explicitly do not specify the level of granularity for an atom or aggregate to remain as generic as possible. A hierarchical structure of containments is not enforced. Instead, *Fragments* can be composed to various combinations.

Product	*Configuration, (consists of *) Fragment*	A *Product* is implied by a configuration. A *Product* is not part of the system's state but can be computed from it based on the configuration.
Unified System	*(Contains *) Fragment, Mapping, Configuration, Constraint, Feature, System Revision*	The *Unified System* represents the unified configurable space regarding spatial and temporal variability. It subsumes concepts from both solution and problem space.
Mapping	*Unified System, (has *) Option variables, (references 1..*) Fragment*	A *Mapping* is an arbitrary expression (e.g., Boolean formula) that consists of *Option* variables that are mapped to fragments. Therefore, the Mapping connects concepts from the solution space (fragments) to concepts in the problem space (options).
Option	*Configuration, Mapping, Feature Option, System Revision*	An *Option* expresses the variability of a system. This can either manifest as variability in space (i.e., *Feature*) or variability in time (i.e. *System Revision or Feature Revision*).
Feature Option	*(Extends) Option, Constraint, System Revision, Feature, Feature Revision*	A *Feature Option* represents the configurable space on feature level.
Feature	*(Contains *) Feature Revision*	" A prominent or distinctive user-visible aspect, quality, or characteristic of a software system or systems [1]"
Revision	*(Has *) predecessor and successor Revision*	A *Revision* evolves along the time dimension and is intended to supersede its predecessor by an increment, e.g., due to a bug fix or refactoring. This relation forms a revision graph, which is a directed acyclic graph (DAG) with each node representing a unique revision.
System Revision	*(Extends) Revision, (defines *) Feature Option, (enables *) Constraint*	A *System Revision* extends the *Revision* and represents the evolutionary state of the entire system at one point in time. This state involves the definition of Features and Feature Revisions (e.g., System Revision 2 involves feature A in revision 1 and Feature B in revision 2) along with Constraints that are valid for the respective System Revision.
Feature Revision	*(has 1 base) Feature, (extends) Feature Option, (extends) Revision*	A *Feature Revision* extends the *Revision* and represents an evolutionary state of one particular *Feature* at one point in time.

Configuration	*(Has a selection of *) Options, implies Product*	A *Configuration* implies one particular *Product* of the *Unified System* and consists of a selection of *Option* variables. It is not part of the system's state.
Constraint	*Unified System, System Revision, (has *) Feature Option*	The *Constraint* is an arbitrary expression (e.g., Boolean formula) that constrains *Feature Options* that can be combined in a *Configuration*.

2 MAPPING

To assess the mapping between concepts and relations of the unified conceptual model regarding the selected tool, each concept and relation is considered separately. For the sake of simplicity, we omit inheritance relationships.

2.1 CONCEPTS

For each concept of the conceptual model listed in Table 3, please inspect whether an equivalent construct exists in your tool and complete the form according to the following scheme in Table 2:

Table 2: Exemplary Mapping of ECCO (incomplete).

Concept in Model	**Maps to Construct (Name)**	**Does not map / Does not exist**	**Please comment, if concept is only partially reflected**
Fragment	Artifact	-	-
Product	-	✓	Because it is not part of the state of the system but exists as output in the form of files in the file system.
System Revision	-	✓	ECCO considers Feature Revisions only.

Table 3: Concept Mapping between Conceptual Model and Tool.

Concept in Model	**Maps to Construct (Name)**	**Does not map / does not exist**	**Please comment, if concept is only partially reflected**
Fragment	Product Element		
Product	Product		
Unified System	Repository (Product Space + Version Space)		
Mapping	Mapping (implicit; elements are annotated with visibilities)		
Option *(abstract)*	Option		

<table>
<tr><td>Feature Option
(abstract)</td><td></td><td></td><td></td></tr>
<tr><td>Feature</td><td>Feature</td><td></td><td></td></tr>
<tr><td>Revision
(abstract)</td><td>Version Dimension?</td><td></td><td></td></tr>
<tr><td>System Revision</td><td>Revision</td><td></td><td></td></tr>
<tr><td>Feature Revision</td><td></td><td>✓</td><td></td></tr>
<tr><td>Configuration</td><td>Choice</td><td></td><td></td></tr>
<tr><td>Constraint</td><td>Dependency</td><td></td><td></td></tr>
<tr><td>Remarks</td><td colspan="3"></td></tr>
<tr><td>Unmapped constructs</td><td colspan="3"></td></tr>
</table>

2.2 RELATIONS

For each relation of the conceptual model listed in Table 5, please inspect whether an equivalent relation exists in your tool and complete the form according to the following scheme in Table 4:

Table 4: Exemplary Mapping of ECCO (incomplete).

Name of Relation in Conceptual Model	**Maps to Relation**	**Does not map / Does not exist**	**If relation is partially mapped, please name divergence (*source, target, multiplicity, direction* and *kind)***
Graph-based Fragment structure	*Tree-based* Fragment structure with cross-tree references	-	Uses strong containment instead of weak containment for children of fragments. To mitigate this limitation, ECCO uses cross-tree references.
Mapping *has 1..** Fragments	*equivalent*	-	
System Revision *defines* * Feature Options	-	✓	ECCO considers Feature Revisions only.

Table 5: Relation Mapping between Conceptual Model and Tool.

Name of Relation in Conceptual Model	**Maps to Relation**	**Does not map / Does not exist**	**If relation is partially mapped, please name divergence (*source, target, multiplicity, direction* and *kind)***
Graph-based Fragment structure	*equivalent* (Tree-based fragment structure (file hierarchy) containing arbitrary models (EMF models) and non-model resources		

	(e.g., plain text and XML files)).		
Product *consists of* * Fragments	*equivalent* (Product-Dimension consists of Product Elements)		
Mapping *has 1..** Fragments	*equivalent* (mapping is implicit)		
Configuration *implies* Product	*equivalent*		
Configuration has a *selection of* * Options		✓	Configuration has a selection of 1..* options (Choice requires all features to be selected or deselected)
Unified System *has* * fragments	*equivalent* (Product Space is contained in the Repository and contains dimensions which contain the fragments)		
Unified System *has* * Mappings	*equivalent*		
Unified System *has* * Constraints	*equivalent* (Feature Model has * constraints)		
Unified System *has* * Features	*equivalent*		
Unified System *has* * System Revisions	*equivalent* (Revision Graph)		
Mapping *has* * Option variables	*equivalent*		
Feature *has* * Feature Revisions		✓	SuperMod considers Revisions of the System (including its Features) but does not apply version control on Features individually.

Constraint *has* * Feature Option variables	*equivalent*		
System Revision *defines* * Feature Options	*equivalent*		
System Revision *enables* * Constraints	*equivalent*		
Revision *has* * successor (Branching/Forking) and * predecessor (Merging) Revisions	*equivalent* Sequence of revisions (subsumed by DAG)		Deliberately no support for branching, but for a (temporary) three-way merge
Unmapped relations in tool			
Remarks			

A. REFERENCES

[1] K. Kang, J. Hess W. Novak, and A. Peterson, "Feature-Oriented Domain Analysis (FODA) Feasibility Study.," Carnegie Mellon University, 1990.

[2] G. Guizzardi, L. F. Pires and M. van Sinderen, "An Ontology-Based Approach for Evaluating the Domain Appropriateness and Comprehensibility Appropriateness of Modeling Languages," *Proceedings of the International Conference on Model Driven Engineering Languages and Systems,* 2005.

[3] S. Ananieva, T. Kehrer, H. Klare, A. Koziolek, H. Lönn, S. Ramesh, A. Burger, G. Taentzer and B. Westfechtel, "Towards a conceptual model for unifying variability in space and time," *Proceedings of the 2nd International Workshop on Variability and Evolution of Software-Intensive Systems,* 2019.