On the Diversity of Capturing Variability at the Implementation Level

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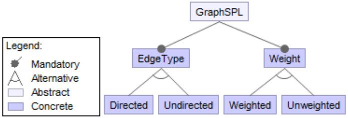
Motivation

Specification Level



mapping

Implementation Level

```
object Conf {
  final val WEIGHTED: Boolean = true
}
abstract class Graph { /* Common part */ }
class ConcreteGraph extends Graph {
  def adddirectededge(s: Vertex, d: Vertex, w: Int) = {
    val edge = new Edge(s, d)
    if (Conf.WEIGHTED) {
      edge.weight = w
    }
    edges = edge :: edges
    addtoadjacencymatrix(edge)
  }
  def addundirectededge(s: Vertex, d: Vertex, w: Int) = {
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    addtoadjacencymatrix(edge2)
  }
  def addedge(callback: (Vertex, Vertex, Int) => Unit,
      x: Vertex, y: Vertex, w: Int = 1) = callback(x, y, w)
```

core-code assets with traditional techniques

- During evolution, their mapping may deteriorate
- It's needed to reconstruct the FM, or part of it
  - Code is not shaped in terms of features

Motivation

Reverse engineering approaches abstract from the implementation technique

- Feature locations
- Reconstructing the FM from the propositional formula, ...
- When a single technique is used (e.g., preprocessors in C)

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Reverse engineering approaches abstract from the implementation technique

- Feature locations
- Reconstructing the FM from the propositional formula, ...
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The addressed issues:

I1. Capturing the variability implementation technique

I2. Capturing features and variation points is not the same

I3. The importance of techniques in a reverse engineering process

Variability Realization

Core-code assets consist of: core, commonalities, variabilities

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Core-code assets consist of: core, commonalities, variabilities

Variable Part: abstractions

commonalities: variation points (*vp*-s)

variabilities: variants

variability implementation techniques

(e.g., inheritance, generic types, design patterns)

Dimensions of Diversity

Features in a feature model:

- Parent-child hierarchy
- Logical relations
- Cross-tree constraints

Variation points with variants:

- A richer set of Characteristic Properties
- Realized by diverse Techniques

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Variation points with variants:

- A richer set of Characteristic Properties
- Realized by diverse Techniques

vp_edgetype (26-27), v_directed (6-13), v_undirected (14-25)

vp_weight (2), v_weighted (2, ‘true‘), v_unweighted (2, ‘false‘)

Characteristic Properties of Variable Parts

- Logical relation
- Binding time
- Defaults
- Granularity
- Evolution
- Quality criteria

- Mandatory
- Optional
- Multi-Coexisting (Or)
- Alternative

vp_edgetype with Alternative (v_directed, v_undirected), Strategy Pattern

Characteristic Properties of Variable Parts

- Logical relation
- Binding time
- Defaults
- Granularity
- Evolution
- Quality criteria

Binding	Values
Static binding (S)	(S) compilation / link (S) build / assembly (S) programming
Dynamic binding (D)	(S/D) configuration (S/D) (re) deploy (D) runtime (start-up) (D) pure runtime (operational mode)

vp_edgetype is bound during Runtime, e.g., to v_directed

Characteristic Properties of Variable Parts

- Logical relation
- Binding time
- Defaults
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- Evolution
- Quality criteria

- Default variant

Some variability may not be subject to frequent variations among the majority of software products in an SPL

v_unweighted is a Default variant of vp_weight

Characteristic Properties of Variable Parts

- ☐ Logical relation
- ☐ Binding time
- ☐ Defaults
- ☐ Granularity
- ☐ Evolution
- ☐ Quality criteria

Granularity	Values
Coarse grained	► Component, framework with plug-ins as variants, file, package, class, interface, frame, feature module, etc.
Medium grained	► Method, field inside a class, aspect, delta module, frame, etc.
Fine grained	► Expression, statement, block of code within a method, frame, etc.

vp_weight at a Parameter level, or v_directed at a Method level

Characteristic Properties of Variable Parts

- ☐ Logical relation
- ☐ Binding time
- ☐ Defaults
- ☐ Granularity
- ☐ Evolution
- ☐ Quality criteria

- Open
- Closed

vp_edgetype is a closed vp, as it can take only ‘true‘ or ‘false‘ values

Characteristic Properties of Variable Parts

- Logical relation
- Binding time
- Defaults
- Granularity
- Evolution
- Quality criteria

- Preplanning effort
- Visibility of variation point
- Information hiding
- Uniformity
- Separation of Concerns (SoC)
- Traceability
- Scalability

Using strategy pattern requires more Preplanning effort than parameters

Classifications of Techniques

1. Based on the emergence time
   - Traditional (*e.g.*, inheritance, generic types, design patterns)
   - Emerging (*e.g.*, frames, feature modules, delta modules)
2. Based on language or tool support
   - Language-based (*e.g.*, inheritance, feature modules, aspects)
   - Tool-based (*e.g.*, frames)
3. Based on how the variability is represented and resolved
   - Annotative (*e.g.*, preproceessor directives, frames)
   - Compositional (*e.g.*, feature modules, delta modules, frames)
     - Positive or Negative variability (*e.g.*, delta modules)

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Catalog Building Method

Covered techniques: Used in a closed-world SPLE process

Excluded techniques: Components, frameworks, ...

Evaluation of techniques

- *First process:* Use 4 small case studies (in Scala)
- *Second process:* An Informed opinion from the existing research works (catalogs, taxonomies, studies,...)

Resulting catalog...

Legend A:
●: good support / belong
◐: possible support (difficult)
○: no support (not often applicable) / does not belong
✱: high; ◖ : average; ◁ : low
E: explicit; A: ambiguous

	Feature types			Binding time			Granularity																
	Optional	*Or*	*Alternative*	*Static (S)*	*Dynamic (D)*	Defaults	Open for evolution	*Coarse*	*Medium*	*Fine*	Preplanning effort	Visibility of *vp-s*	Information hiding	Uniformity	Sep. of concerns	Traceability	Scalability	Language paradigm	Annotative	Compositional	Language-based	Tool-based	Traditional	Emerging
AD-HOC REUSE																								
Cloning / Patching	●	●	●	● 7	○ 7	○ 7	● 7	● 7	●	●	◁	A/E 7	○ 7	●	○ 7	○ 7	○ 7	Not specific 7	●	●	●	○	●	○
Conditional Execution (Parameters)	● 7	○ 7	● 7	◐ 1,7	● 1,7	○ 7	○ 7	○ 1,7	◐ 1,7	● 1,7	◁ 1	A 7	◐ 1	○ 1	◐ 1,7	◐ 1,7	○ 1	Not specific 7	● 1	○ 1	● 1	○ 1	● 1	○ 1
METHODOLOGICAL REUSE																								
Preprocessor directives	● 2,3,4,7	◐ 2,4	● 1,2,3,4,7	● 1,2,7	○ 1,2,7	◐ 6,7	○ 7	● 1,3,4,6,7	● 1,3,4,6,7	● 1,3,4,6,7	◁ 1,7	A/E 7	○ 1	● 1	○ 2,7	◐ 1,2	◐ 2,7	Not specific 7	● 1,2,4,6	○ 1,4,6	○ 1,3,4,6	● 1,3,4,6	● 1,3	○ 1,3
Argument defaulting	● 4	○ 4	○ 4	●	○	● 6	○	○	●	○	◖	A	◐	○	○	◐	◐	Not specific	● 3,4,6	○ 3,4,6	●	○	● 3	○ 3
Overriding	◐	●	○	○	●	●	●	○	●	○	◁	A	●	○	●	●	●	O. Oriented	○	●	●	○	●	○
Aggregation / Delegation	● 2	◐ 2	◐ 2	● 2	● 2	●	◐	●	●	○	◖	E	◐	○	● 2	◐ 2	◐ 2	O. Oriented 2	● 2	● 2	●	○	●	○
Inheritance	● 2	● 2	◐ 2	● 2,6	● 2,6	●	●	● 6	● 6	○ 6	◖	A	● 6	○ 1	● 2	● 2	◐ 2	O. Oriented 6	◐ 2,6	● 2,6	● 6	○ 6	●	○
Reflections	● 2	● 2	● 2	◐ 2	● 2	●	◐	●	●	○	✱	E	●	○	● 2	● 2	● 2	O. Oriented	○	●	●	○	●	○
Aspects	◐ 2,4	● 2,4	◐ 2,4	● 1,2,7	◐ 1,2,7	● 7	● 7	◐ 1,7	● 1,7	○ 1,7	◖ 1,7	A 1,7	○ 1	◐ 1	● 1,3,7	● 1	● 2,7	Aspect Ori. 1,3	◐ 2	● 1,2,3	● 1,3,7	○ 1,3,7	○ 1,3	● 1,3
Polymorphism																								
Coercion (Casting)	◐ 4	◐ 4	◐ 4	●	○	● 4	●	●	○	○	✱	A	●	○	●	●	●	O. Oriented 3,4	○	●	●	○	● 3	○ 3
Overloading	○ 2,4	○ 2,4	● 2,4	● 2,6	○ 2,6	●	●	○ 6	● 6	○ 6	◖	A	●	○	◐ 2	◐ 2	◐ 2	Procedural 3,4	● 2,6	● 2,6	●	○	● 3	○ 3
Subtype polymorphism	◐ 4,7	◐ 3,4	● 3,4,7	◐	● 3,4,7	● 6	● 7	● 7	● 7	○ 7	✱	A 7	●	○	● 7	●	●	O. Oriented 3,4	○	● 7	● 7	○ 7	● 3	○ 3
Parametric polymorphism (generics)	◐ 3,4,7	● 3,4	● 3,4,7	● 3,4,6,7	○ 3,4,6,7	○ 7	○/●	● 6	● 6,7	○ 6,7	✱	E 6,7	●	○	◐	●	◐	Generic prog. 3,4	● 6	● 7	● 4,7	○ 4,7	● 3	○ 3
Design patterns																								
Strategy pattern	● 1	● 1	● 1	◐ 6	● 1,6	● 1	●	●	● 1	○	✱ 1	A	● 1	○ 1	● 1	● 1	●	O. Oriented	○ 1	● 1	● 1	○ 1	● 1	○ 1
Decorator pattern	● 1	● 1	○	◐	● 1	●	●	●	●	○	✱ 1	A	● 1	○ 1	● 1	● 1	●	O. Oriented	○	●	●	○	●	○
Observer pattern	●	●	●	◐	● 1	●	●	●	●	○	✱ 1	A	● 1	○ 1	● 1	● 1	●	O. Oriented	● 1	● 1	● 1	○ 1	● 1	○ 1
Template method pattern	● 1	◐ 1	● 1	◐ 6	● 1,6	● 1	●	●	● 6	○	✱ 1	A	◐ 1	○ 1	● 1	● 1	●	O. Oriented	○ 1	● 1	● 1	○ 1	● 1	○ 1
Visitor pattern	◐	●	◐	◐	●	●	◐	●	●	○	✱	A	●	○	●	●	●	O.Oriented	○	●	●	○	●	○
Emerging techniques																								
Frames	● 2,5	● 2,5	● 2,5	● 2,5,7	○ 2,5,7	● 5,7	○/● 7	● 5,7	● 5,7	● 5,7	◖ 2,7	E 5,7	○	◐ 1	● 2,7	● 2	◐ 2,7	Not specific 5,7	● 2,5	● 2,5	○ 5,7	● 5,7	○	●
Feature Modules	◐ 4	● 1,3,4	◐ 4	● 1	◐ 1	●	●	● 1	● 1	○ 1	◖ 1	A	○ 1	● 1	● 1,3	● 1	●	Feature Ori. 1	○ 1	● 1,3	● 1,3	○ 1,3	○ 1,3	● 1,3
Delta Modules	◐	●	◐	● 1	○	●	●	● 1	● 1	○ 1	◖	A	○	◐	●	●	●	Delta Ori. 1	● 1	● 1	● 1	○ 1	○ 1	● 1

Legend B: 1 → Apel [2]; 2 → Gacek [13]; 3 → Muthig [22]; 4 → Patzke [25]; 5 → Patzke [26]; 6 → Coplien [9]; 7 → Patzke [24]

Capturing Variability

Feature Modules

```
layer BasicGraph;
class Graph {
  Vector nodes = new Vector();
  Vector edges = new Vector();
  Edge add(Node n, Node m) {
    Edge e = new Edge(n, m);
    nodes.add(n);
    nodes.add(m);
    nodes.add(e);
    return e;
  } /* ... */
class Edge {   /* ... */ }
class Node {   /* ... */ }
}

layer Directed;
 class Graph { /* ... */ } /* ... */

layer Undirected;
class Graph { /* ... */ } /* ... */

layer Weighted;
class Graph { /* ... */ }
class Edge { /* ... */ }
class Weight { /* ... */ }
```

Strategy pattern with Parameters

```
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```

Capturing Features

Logical Relation: BasicGraph (mandatory), Directed, Undirected, Weighted (optional)

Binding time: deployment; **Granularity**: feature module; No **Evolution** or **Default** concepts (Unweighted is default)

Capturing Variability

Capturing VP-s with Variants

VP-s	Lines	Granularity	Binding time	Logical Rl.	Evolution
`vp_edgetype`	26 – 27	method	runtime	alternative	Open
`vp_weight`	2	parameter	programming	alternative	Close

Variants	Lines	Granularity	Default	*VP*-s
`v_directed`	6 – 13	method	No	`vp_edgetype`
`v_undirected`	14 – 25	method	No	`vp_edgetype`
`v_weighted`	2	value	No	`vp_weight`
`v_unweighted`	2	value	Yes	`vp_weight`

Legend A:
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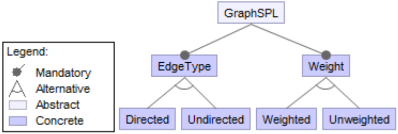
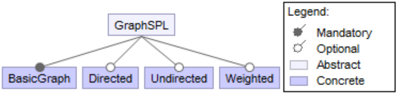
Strategy pattern	●	●	●	◐	●	●	●	●	●	○	✱	A	●	○	●	●	●	O. Oriented	○	●	●	○	●	○
	1	1	1	6	1,6	1			1		1		1	1	1	1			1	1	1	1	1	1

Capturing Variability

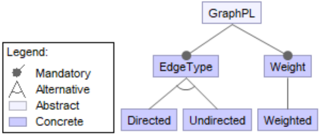
Reconstructing the Feature Model



Capturing Features



Capturing VP-s with Variants



Summary and Future Work

Addressed issues

- Capture the variability implementation techniques (**I1**)
- Both features and vp-s with variants can be used to capture the variability; their meaning overlap but is not the same (**I2**)
- We study the diverse properties that can be captured during reverse engineering (**I3**)

Summary and Future Work

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Availability Case studies and a DSL:
https://github.com/ternava/variability-cchecking

Future Work

- Using vp-s with variants during the migration of some product variants as an SPL
- Demonstrate the usage of the catalog