Concept Analysis for Product Line Requirements

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Outline

⇨ Introduction
  ⇨ Role of aspects in SPL RE
  ⇨ FRPs, SEI’s scenarios, FCA

⇨ How can aspects help?

⇨ Case study

⇨ Concluding remarks
Product Lines Are Everywhere

Big Mac

Filet-O-Fish

McRib

Big N’ Tasty
Methods in SPL Development

Cumulative Cost

Number of products

One-of-a-kind Development

New: Extractive & Reactive

Traditional: Proactive
Requirements As An Asset

⇒ Requirements reuse
  ◦ Closer to system’s initial concepts
  ◦ More effective than code-level reuse

⇒ Existing methods characterize a SPL’s requirements using either functional or quality criteria
  ◦ CCCs (aspects) emerge
Role of Aspects in SPL RE

- Enhancing modularity
- Detecting interferences
- Analyzing trade-offs
- Supporting evolution
FRPs

- Functional Requirements Profiles [Niu & Easterbrook, RE’08]
  - Action-oriented concerns that bear a high information value of a document
  - Model user-visible system functionalities
  - Represented by “verb-direct object” pairs
  - Extraction algorithm based on IR, NLP, and Information Theory

- Sample media-shop FRPs
  - navigate shop, search product, customize toolbox ...
Quality Requirements

- Describe desired system qualities
  - Reliability, usability, portability, understandability, modifiability, robustness ...
  - aka: nonfunctional requirements, quality attributes, softgoals, “-ilities”

- SEI’s quality attribute scenarios
  - Provide operational definition
  - Making qualities measurable
  - Context-dependent
“Modifiable”

“A developer wishes to add a searching input field and button to the UI code, as well as to resize the toolbar icons; modifications shall be made with no side effect in three hours; the resulting system addresses items 5 and 13 in version 1.0.2’s bug report so usability is expected to increase.”
(Formal) Concept Analysis

⇒ A concept is always defined within the context
⇒ A concept is characterized by extents and intents

<table>
<thead>
<tr>
<th>MEDIA SHOP</th>
<th>free-distribution</th>
<th>timely</th>
<th>paper</th>
<th>sound</th>
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<tr>
<td>CD</td>
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<tr>
<td>MAGAZINE</td>
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<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>NEWSPAPER</td>
<td>X</td>
<td>X</td>
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<tr>
<td>VIDEOTAPE</td>
<td></td>
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<tr>
<td>BOOK</td>
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</table>

(a) Formal context.

<table>
<thead>
<tr>
<th>T</th>
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<td>{{CD, VIDEOTAPE}, {sound}}</td>
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<td>⊥</td>
<td>{{}, {free-distribution, timely, paper}}</td>
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</table>

(b) Concepts for the formal context.
Concept Lattice

⇒ Subconcept-superconcept relation
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Extractive SPL RE -- Symmetric View of Aspects

⇒ Every aspect represents a concern in its own dimension, and is projected to other dimensions according to its impacts on other concerns

⇒ Issue 1: Locate concerns
⇒ Issue 2: Detect interferences
Extraction & CCCs

⇒ 3 scenarios, 7 FRPs, 3 quality requirements

**Table 1: Extracted Requirements Constructs**

<table>
<thead>
<tr>
<th>Functional Requirements Profiles</th>
<th>Quality Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRP₁: navigate shop</td>
<td>Q₁: +U (positively contribute to usability)</td>
</tr>
<tr>
<td>FRP₂: search product</td>
<td>Q₂: +A (positively contribute to accessibility)</td>
</tr>
<tr>
<td>FRP₃: customize toolbox</td>
<td>Q₃: −M (negatively contribute to maintainability)</td>
</tr>
<tr>
<td>FRP₄: select language</td>
<td></td>
</tr>
<tr>
<td>FRP₅: monitor quantity</td>
<td></td>
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<tr>
<td>FRP₆: generate report</td>
<td></td>
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<tr>
<td>FRP₇: create account</td>
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</tbody>
</table>

**Table 2: Crosscutting Relations**

<table>
<thead>
<tr>
<th></th>
<th>FRP</th>
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<tr>
<td>Sce₁</td>
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<td>×</td>
<td>×</td>
<td>×</td>
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<td></td>
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<td>Sce₂</td>
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</tbody>
</table>
Issue 1: Locate Concerns

Problem: Identify the functional units (FRPs) that contribute to a particular system quality.

Solution

Implications

More accurate starting point for defining join points
Issue 2: Detect Interferences

⇒ Problem: How a pair of homogeneous requirements interact with each other.

⇒ Solution

⇒ Implications
  ⇒ Analyzing trade-offs, e.g., disjoint, orthogonal
Reactive SPL RE -- Asymmetric View of Aspects

- Extractive SPL RE -- symmetric
  - Static and micro-level view within the SPL, which focuses on internal interactions

- Distinguishes the base from aspects
  - Dynamic and macro-level view over the SPL, which focuses on evolution and impacts

- Issue 3: Incremental lattice update
- Issue 4: Change impact analysis
Issue 3: Update Concept Lattice

⇒ Problem: Modify the concept lattice efficiently as the SPL evolves.

⇒ Solution (algorithm)

⇒ Implications
  ⇨ Spot change on-the-fly; without re-building
Issue 4: Change Impact Analysis

Problem: Does a change of the fulfillment of a requirement affect the fulfillment of another requirements?

Solution (heuristics)

- Qualities: top-down
- FRPs: bottom-up

Implications

- Trade-offs, priorities, preferences
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Background

 Mobile soccer game SPL

Produced by a small company (~50 employees)

Validation meetings

  2-hour meeting: Validate FRPs, elicit scenarios, identify quality attributes
  Half-day JAD (Joint Application Development) workshop
Results

Table 3: Extractive Analysis Results

<table>
<thead>
<tr>
<th>Constructs</th>
<th>#</th>
<th>Concerns</th>
<th>#</th>
<th>Pre.*</th>
<th>Interferences</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roles</td>
<td>3</td>
<td>Specific</td>
<td>2.7</td>
<td>88.9%</td>
<td>Utility</td>
<td>2</td>
</tr>
<tr>
<td>FRPs</td>
<td>17</td>
<td>Rel., Pert.*</td>
<td>6</td>
<td>78.9%</td>
<td>Conflict</td>
<td>2</td>
</tr>
<tr>
<td>Drivers</td>
<td>7</td>
<td>Shared</td>
<td>6</td>
<td>57.5%</td>
<td>Variability</td>
<td>0</td>
</tr>
<tr>
<td>Scenarios</td>
<td>12</td>
<td>Irrelevant</td>
<td>2.3</td>
<td>54.4%</td>
<td>Coupling</td>
<td>5</td>
</tr>
</tbody>
</table>

* Precision
* Relevant, Pertinent

- Demonstrates applicability and usefulness
- Threats to validity
Discussion & Lessons Learned

- Automation vs. manual effort

- Scenario generation ≈ test case generation
  - In our case: 4 scenarios for each of the 3 stakeholder roles in half an hour

- “Crosscut follows form; form follows function”

- Coupling isn’t necessarily a bad thing
  - Organizational coupling reduces latency
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Concluding Remarks

- New method in SPL development
  - Extractive & reactive

- Aspects can help (in addressing 4 issues)
  - Extractive: symmetric view of aspects
  - Reactive: asymmetric view of aspects

- Aspects as a powerful tool in conceptual modeling (SE, DB, …)
Acknowledgments

⇒ Partner company

⇒ John Mylopoulos, Krzysztof Czarnecki

⇒ Anonymous AOSD’09 reviewers