A Systematically Conducted Literature Review: Quality Attribute Variability in Software Product Lines

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Research motivation

• It seems that software product lines (SPLs) differentiate products with functional features
  – Quality attributes, such as performance, security, and reliability, are not often varied in SPLs
  – The research on quality attribute variability is still immature and its state-of-the-art unclear

• Contribution: to provide a systematically conducted literature review on quality attribute variability in SPLs
  – Scope was set to the primary studies published in SPLC (Software Product Line Conference)
Research method motivation

• Although becoming popular in SE, systematic literature reviews (SLR) had certain drawbacks for our purpose

• SLRs typically include and exclude studies based on metadata, e.g., titles and abstracts
  – We knew of several relevant studies on quality attribute variability that were not recognizable by their metadata

• Difficult to construct search strings for a topic with synonyms and no established terminology
  – Example search string for quality attribute variability in software product lines: 122190 hits in IEEE database when searching all content; and 408 when searching metadata only
Research method

• Manual reading instead of search strings
  – Read through all full publications in SPLC conferences (221 in total between years 2000 and 2010)
  – Read through all content, also examples and diagrams

• Predefined inclusion and exclusion criteria, study selection replication, data extraction, and qualitative analysis and synthesis

• Aims of SLR: completeness, objectiveness, replicability, possibility to assess validity
  – Completeness: scope limited to in one forum, but more detailed study identification in that one forum
  – Others are more or less similar as in traditional SLR
Research questions

- RQ1: What is the rationale for varying quality attributes in software product lines?
- RQ2: How is quality attribute variability in software product lines captured?
- RQ3: Which specific quality attributes are varying?
- RQ4: What empirical evidence exists about varying quality attributes in industrial software product lines?
Key observation: influence of feature modelling

- Feature modelling strongly influences proposed approaches, for example:
  - Varying quality attributes are captured as "quality attribute features"
  - Varying quality attributes are embedded into features

- Can a paradigm that is suitable for functionality be also applied to quality attributes?
  - For functional features, it is easier to say when they are "in" or "out"
  - For some qualities, it is about "more" or "less"

- How should software architecture be taken into account?
  - The realization of (or impact on) quality attribute variability is analyzed only against features
  - Are quality attributes just byproduct of features?
Example: capturing varying quality attributes as “quality attribute features”

1. Varying quality attributes captured as

   - Quality attribute features
   - Embedded to features or components
   - Other

Example for usability:

(Lee et al., 2010)
Example: capturing quality attributes embedded into features

1. Varying quality attributes captured as

Example where features are attached with memory consumption:

[Selected] recv_keep_alive:mem = 4

(Tun et al., 2009)
Key observation: different quality attributes are treated differently

- Different quality attributes were treated differently in the primary studies
  - See comparison of approaches for capturing quality attribute variability against four commonly varied quality attributes

- Different quality attributes are inherently different
  - Some approaches fit these inherent characteristics better than the others
  - In the examples: embedding memory consumption metrics into features, or using discrete quality attribute features for usability
  - The approaches should make their assumptions about characteristics of quality attributes visible

- There may not be "one-size-fits-all" approach for quality attribute variability
# How specific quality attributes and their variability are captured

<table>
<thead>
<tr>
<th>QA captured as</th>
<th>Memory consumption</th>
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<tbody>
<tr>
<td>Quality attribute features</td>
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<td>[10, 27]</td>
<td>[9, 10]</td>
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<tr>
<td>Embedded to entities</td>
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<td>[2, 14, 21, 37, 39]</td>
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<tr>
<td>Other</td>
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<tr>
<td>Variant space captured as</td>
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Key observation: empirical evidence is lacking

- Not much empirical evidence on industrial companies with varying quality attributes
  - Two primary papers with direct empirical evidence
  - Some papers utilize an example and mention an industrial SPL
- There is a need of empirical descriptive accounts, e.g., rigorous case studies (Yin, 1994)
  - Instead of new solutions, need to understand the real world problem that should be solved
  - Why quality attributes vary, which quality attributes vary, how they vary, how variability is managed and realized…
Conclusions

• Feature modelling strongly influences proposed approaches for quality attribute variability in SPLs
• Different quality attributes are (and should be) treated differently
• Empirical evidence of industrial companies with varying quality attributes is lacking
• We are expanding the set of primary studies, e.g., with backward and forward references
  – Thus we are able to study the generalizability of our results beyond the scope of SPLC
Inclusion and exclusion criteria

• *Inclusion*: says explicitly or uses an example/case where quality attributes vary in a software product line. Varying means that different products in a software product line have different levels of quality attributes.

• *Exclusion*: contributes to quality variability by only using common feature definitions: a feature "is a user-visible aspect, quality, or characteristic" [19] or "is specified by a set of functional and quality requirements" [4]. These studies had too little contribution to be subjected to analysis.

• *Exclusion*: does not address quality attributes observable via execution [3]. Varying quality attributes are argued to be observable via execution [6]. In fact, no concrete counterexamples were found in the manual reading.
RQ1: What is the rationale for varying quality attributes in software product lines?

Rationale: Variation in user and usage needs

Rationale: Variation in HW, resources, functionality

Strategy: differentiation

Strategy: adaptation

Strategy: impact management
RQ2: How is quality attribute variability in software product lines captured?

1. Varying quality attributes captured as

2. Possible variant space captured as

- Quality attribute features
  - Embedded to features or components
  - Other

- Numeric metric
- Discrete, ordered levels
- Discrete characteristics
RQ3: Which specific quality attributes are varying?

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RQ4: What empirical evidence exists about varying quality attributes in industrial software product lines?

- Two primary papers with direct empirical evidence on industrial cases of quality attribute variability
  - Not very detailed description of quality variability in these two, e.g., in respect to our research questions

- Some papers both utilize an example and mention an industrial SPL
  - Unknown which parts of the examples are directly from the industrial cases

- Some papers use just an example
  - Not empirical evidence