Considering Feature Interactions in Product Lines

Towards the Automatic Derivation of Dependencies Between Product Variants

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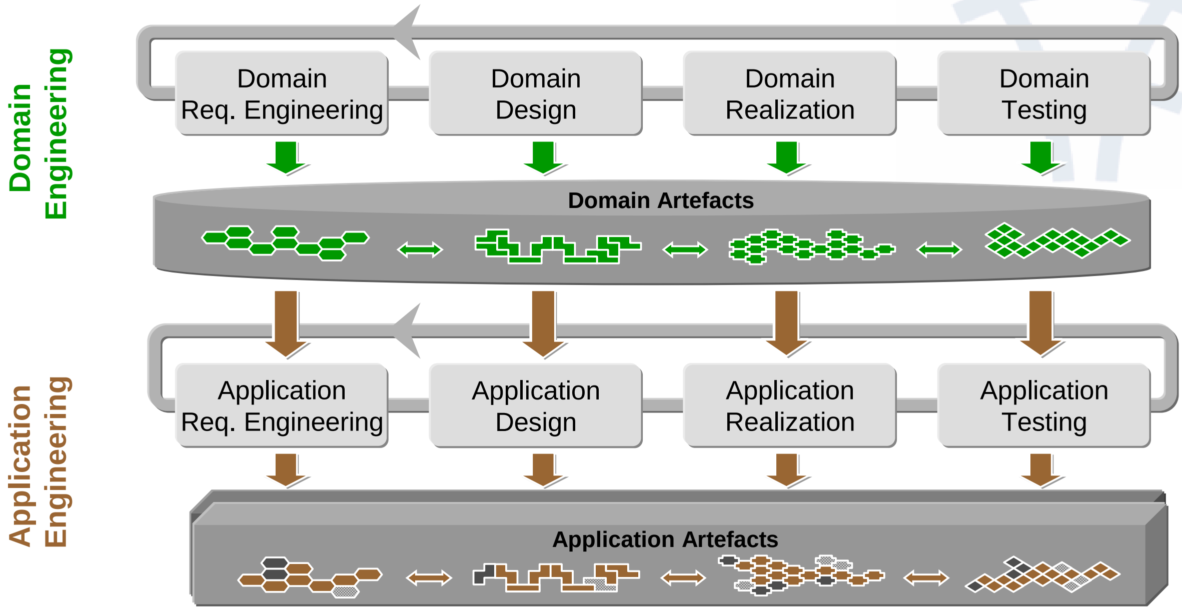
Outline

- **Introduction**
- **Variability in Software Product Lines**
- **Deriving Dependencies between Product Variants**
- **Conclusion**

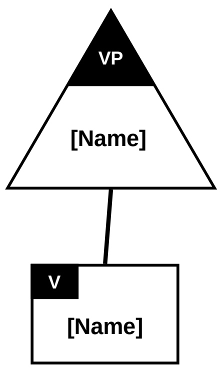
Introduction:
Software Product Line Engineering

- Development approach for customer specific software
  - **Systematic reuse**
    → Reduction of development cost and time; Increase in Quality
- **Two development processes**



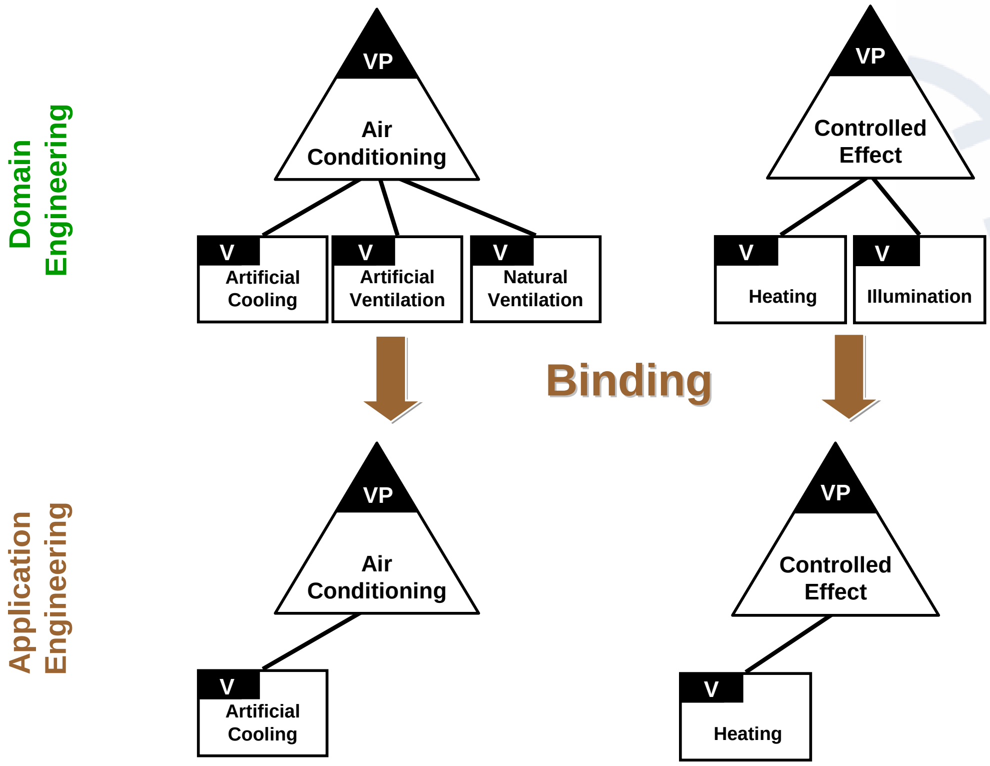
Introduction:
The Concept of Variability (1)

- **Variability**
  - "Ability of an artefact to be adaptable"
- Employing variability
  - **Domain engineering:**
    - **Modelling** of "generic" **domain artefacts**
  - **Application engineering:**
    - **Binding** the variability of the domain artefacts
- **Variation point (VP)**
  - Point at which an artefact can vary
- **Variant (V)**
  - Concrete instances or alternatives for variable parts
  - associated to one VP



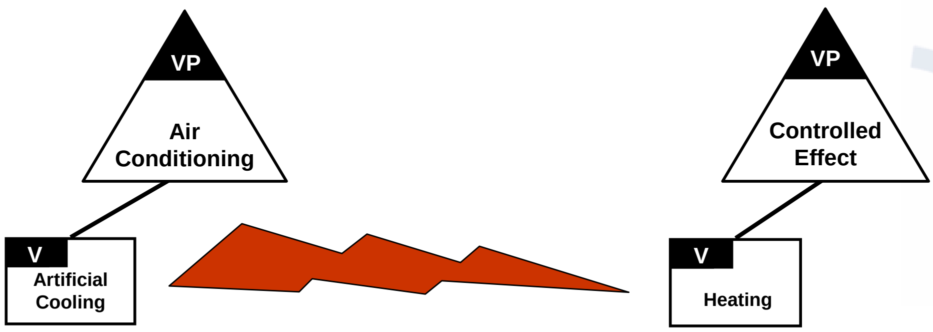
Introduction:
The Concept of Variability (2)

- **Example: “Small Building Control System Familiy”**



Introduction:
Dependencies between Variants (1)

- **Problem: Variants can influence each other**



→ **Consider dependencies** during application requirements engineering
  – Example: artificial cooling ***hinders*** heating

  → customer is **aware** that “artificial cooling” will impact “heating”
  → **choice of alternatives** is possible (e.g., natural ventilation, integrated HVAC, …)

- **Problem:** Dependencies have to be known **before** application requirements engineering
  – otherwise: frustration of customers

Introduction: Dependencies between Variants (2)

- **Solution: Identify dependencies in domain engineering**
  - All possible applications have to be considered

- **Problem:** Number of possible combinations of variants
  - Small example: 5 variants → (3+2+1) * (2+1) = **18 applications**
  - Large example: 14 variants → **639 applications**
  - In practical contexts: > 100 variants → **>> 1000 applications**

  → Manual identification of dependencies does not scale!

- **Our solution:** Semi-automatic approach based on feature interaction detection
  - **Feature interaction between V_j and V_k → dependency between V_j and V_k**

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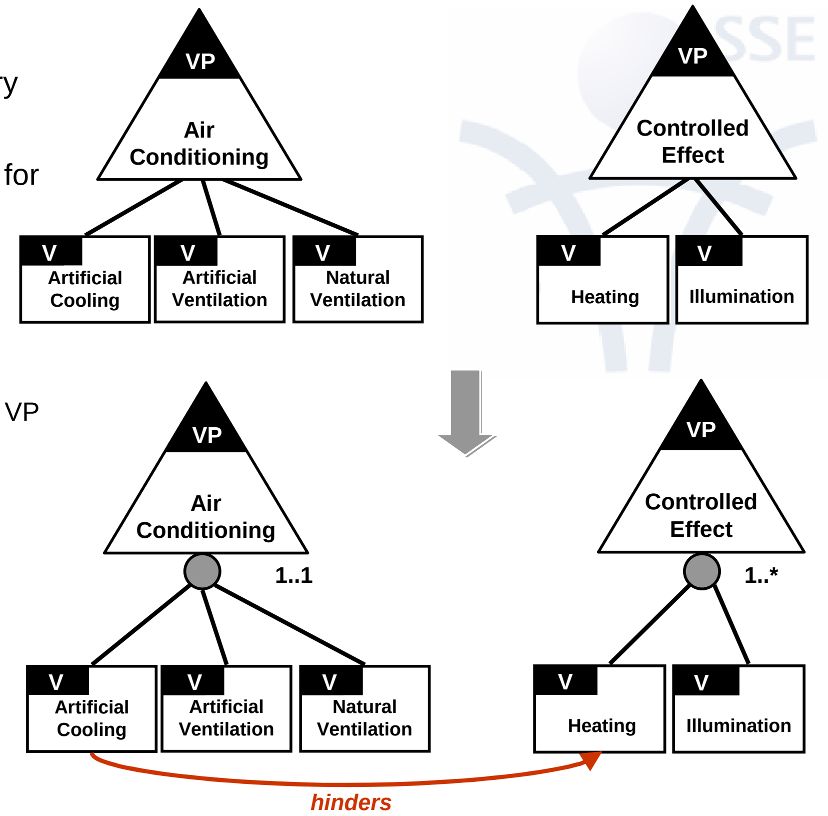
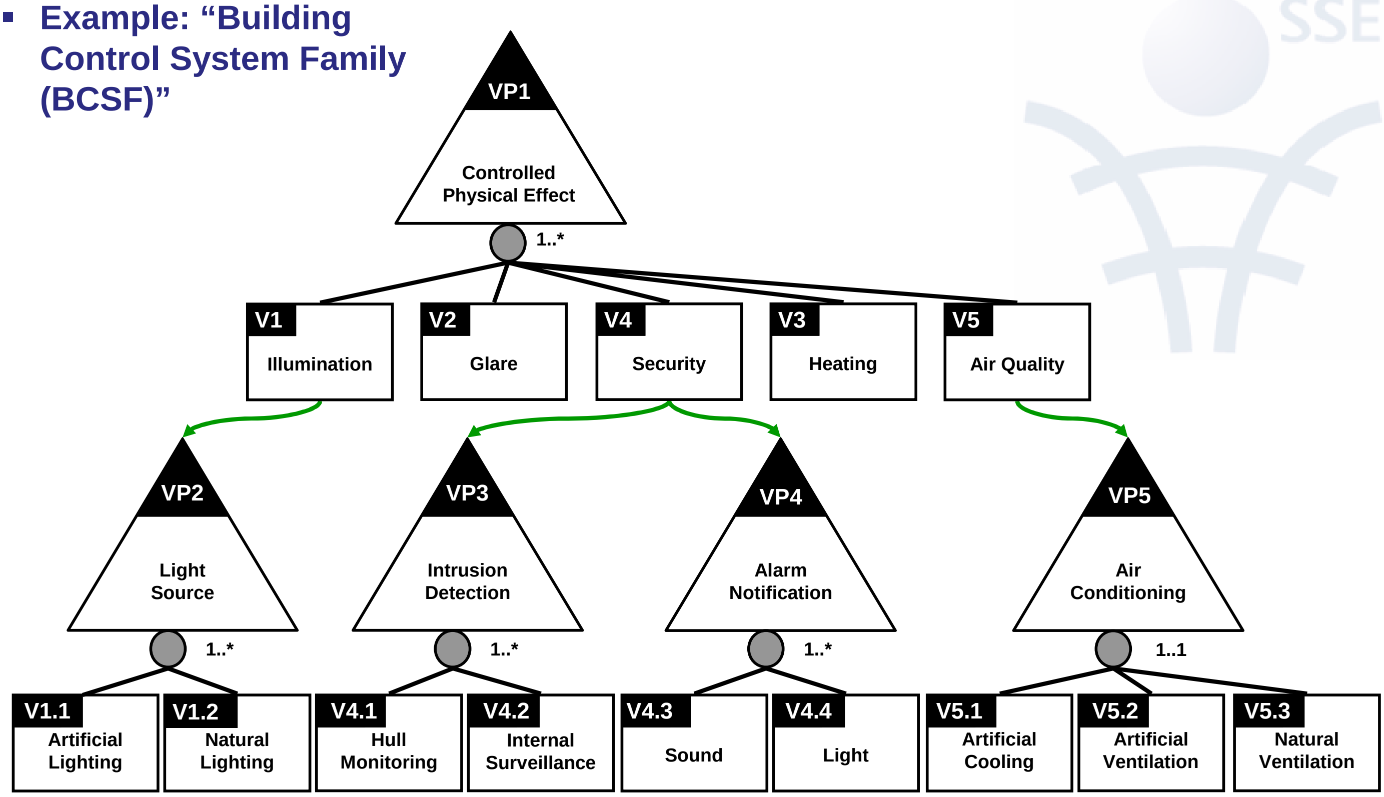
Variability in Software Product Lines: Variability Model (1)

- **Variation point (VP)**
  - Point at which the artefact can vary
- **Variant (V)**
  - Concrete instances or alternatives for variable parts
  - associated to one VP
- **VP-V Dependency**
  - **Variant Group (VG)**
    - Constrains selection of variants for VP
- **V-VP Dependency**
  - Allows hierarchical refinement
- **V-V Dependency**
  - Dependencies between variants
    - **hard:** excludes / requires
    - **subtle:** hints / hinders
- similarities with feature diagrams



Variability in Software Product Lines: Variability Model (2)

- **Example: "Building Control System Family (BCSF)"**



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Deriving Dependencies between Product Variants: Basic Approach

1. **Automatically** determine **feature interactions** for all possible applications

   1.1 Select **representatives** from all possible combinations

   → Tackling the problem of scale

   for each representative:

   1.2 Derive "application" by binding variants

   1.3 Detect feature interactions

   - using algorithm from single system development

2. **Manually** derive and model **dependencies**

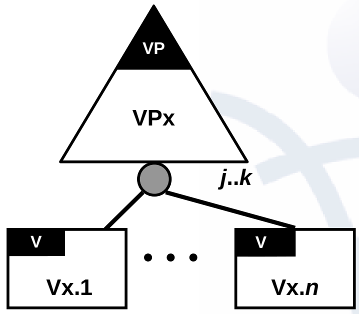
   2.1 Determine relevant feature interactions

   → Relevance cannot be derived from input models

   2.2 Model dependencies between variants

Deriving Dependencies between Product Variants: 1.1 Select Representatives (1)

- Number of possible **variant combinations** for one VG



$$K(j,k,n) = \sum_{i=j}^{k} \binom{n}{i}$$

  – BCSF Example: 639 combinations

- Assumption: **no *m*-way feature interactions**
  – *m*-way feature interaction :=
    feature interaction that does not occur between $1 < r < m$ features but occurs among m features
  – interaction between features $F_1, \ldots, F_m$
    $\Rightarrow$ interactions between all features $F_{i1}, \ldots, F_{ir} \in \{F_1, \ldots, F_m\}$ with $1 < r < m$

➔ **Select** combination with **largest possible number of variants**:
  – "worst case": false positives → more interactions to check manually

$$K(j,k,n) = \binom{n}{k}$$

  – BCSF Example: 639 → 3

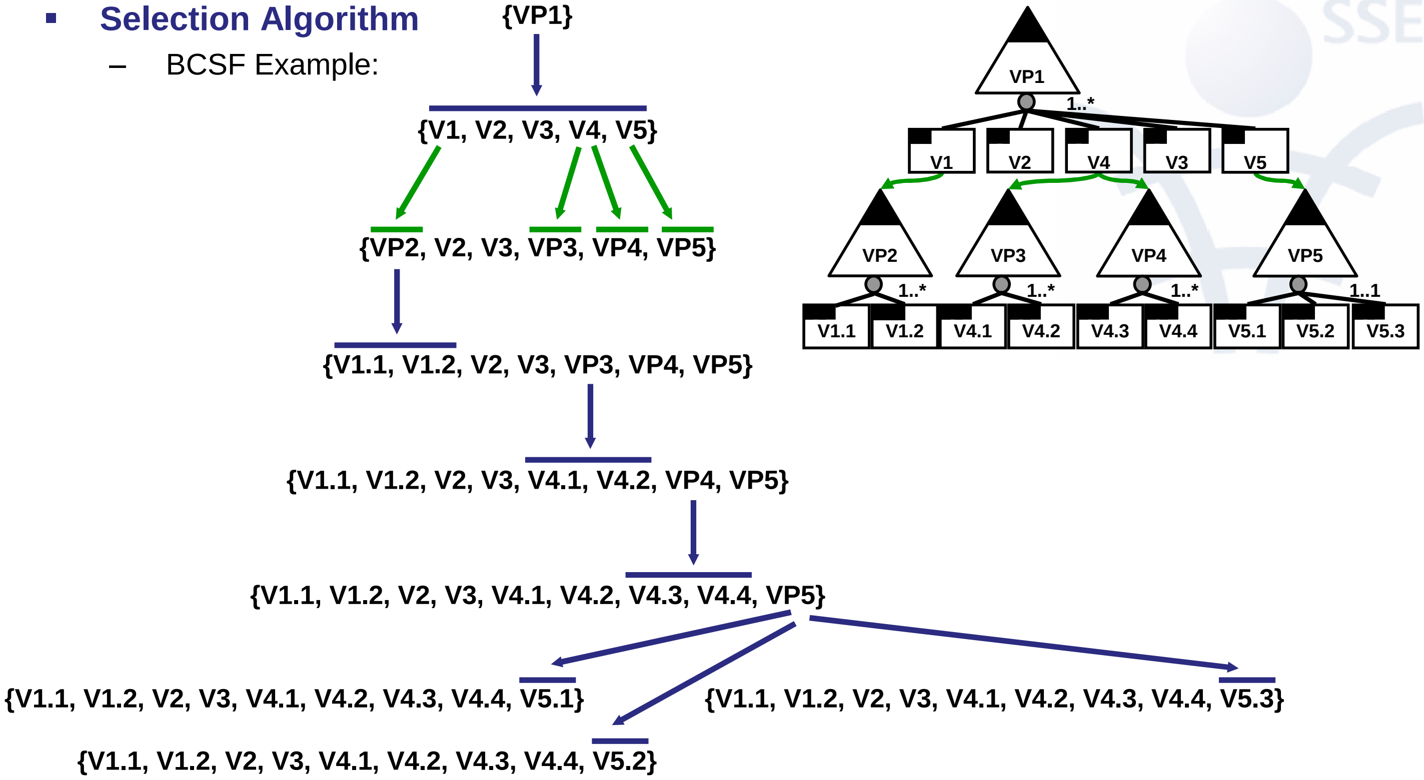
Deriving Dependencies between Product Variants: 1.1 Select Representatives (2)

- **Selection Algorithm ("Outline")**

1. Start with root VP
2. Resolve VP by adding maximum number of variants
   - considering alternatives if $k < n$
3. Resolve hierarchical variants (replace by VP)
4. Repeat at 2. until no more VPs are contained

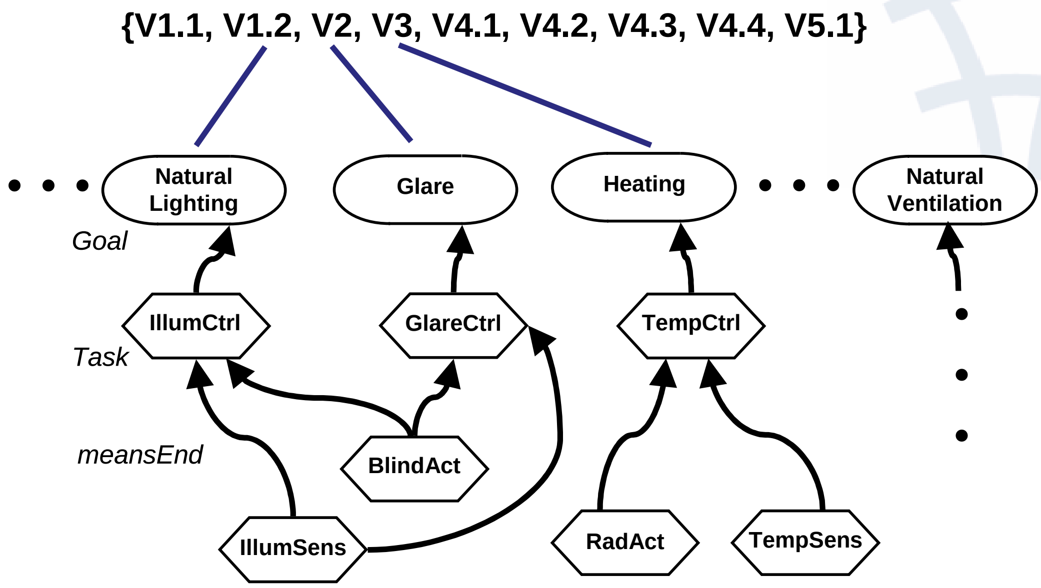
Deriving Dependencies between Product Variants: 1.1 Select Representatives (3)

- **Selection Algorithm**
  - BCSF Example:



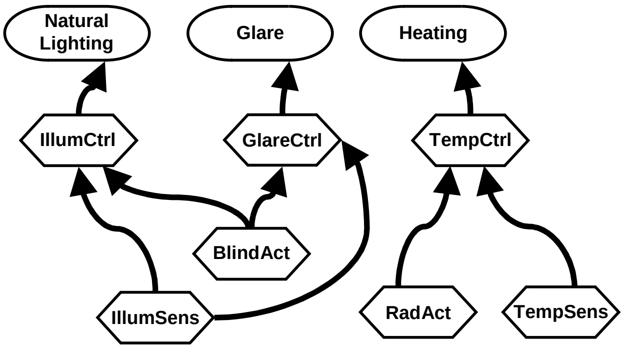
Deriving Dependencies between Product Variants: 1.2 Derive "Application" (2)

- **Bind variants in GRL (Goal Oriented Requirements Language) models**
  - Each variant is assigned to one goal
  - BCSF Example (Excerpt):



Deriving Dependencies between Product Variants: 1.3 Detect Feature Interactions

- **Detect points of interaction (cf. [Metzger et al. 2003], [Metzger 2004])**
  - Point of interaction := task that
    - contributes to the realization of more than one goal
    - has more than one direct parent
    - does not realize goals only
  - Recursive algorithm on GRL metamodel instance
  - BCSF Example:



  - Interaction between **NaturalLighting**, **Glare** ➔ Interaction between **V1.2**, **V2**
  - **Extension for embedded systems:**
    - Additionally consider environment

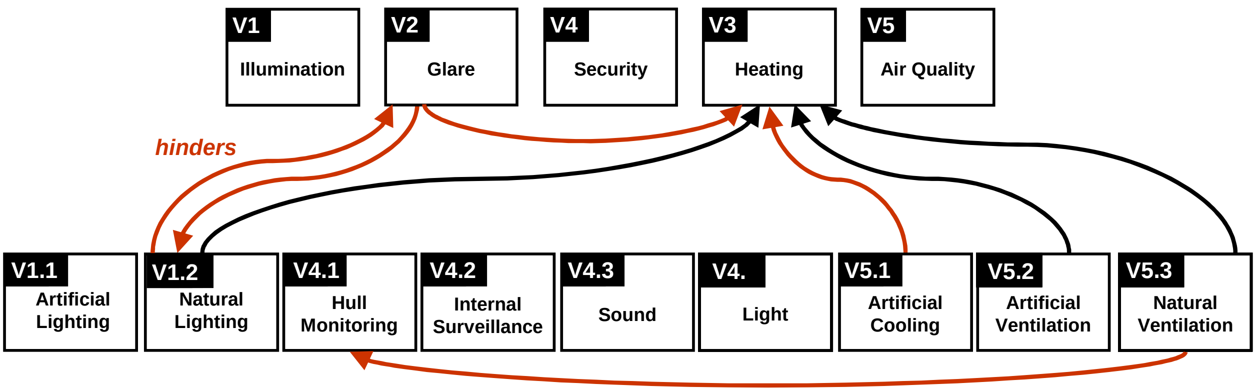
Deriving Dependencies between Product Variants: 2. Manually Derive and Model Dependencies

2.1 Determine relevant feature interactions

- BCSF example:
  1. **{V1.2, V2}** @ **Task**
  2. **{V1.1, V1.2, V2, V3, V4.2}** @ **Task**
  3. **{V1.1, V1.2, V2}** @ **Task**
  4. **{V1.2, V2, V3, V5.2}** @ **environment**
  5. **{V1.2, V2, V3, V5.1 }** @ **environment**
  6. **{V4.1, V5.3}** @ **environment**
  7. **{V1.2, V2, V3, V5.3}** @ **environment**

2.2 Model dependencies between variants

- BCSF example:



Conclusion

- **Semi-automatic approach**
  - Reduction of complexity/effort
    - Automatic selection of representatives: **639** → **3**
    - Automatic detection of interactions: **37** goals/tasks, **39** means-end-links → **7** interactions

- **Model-based approach**
  - Inputs/outputs are models
  - Model-based implementation of detection tool
    - Core: 175 manually implemented Java LOCs

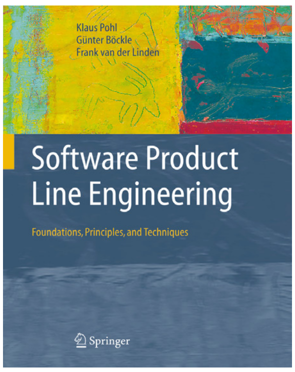
- **Generality of approach**
  - Variability model → feature diagrams could also be used
  - Requirements model (GRL) → other detection approaches are applicable

"Positive" use of Feature Interactions for Product Line Engineering
→ Selection of alternatives to **"avoid" undesired interactions**

Further Information …

… Text Book:

Pohl, Böckle, van der Linden:
Software Product Line Engineering – Foundations, Principles and Techniques.
Springer, 2005



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… Questions?