# Software Reuse and Reusability based on Requirements: Product Lines, Cases and Feature-Similarity Models

**Hermann Kaindl, Mike Mannion**

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## Structure

- Introduction
- Part 1: Motivation for Retrieving Similar Products in Software Product Lines
- Part 2: Feature Model Based Development
- Part 3: Case-Based Reasoning
- Part 4: Similarity Matching in Software Product Line Development
- Summary and Conclusion

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# Part 1

- Motivation for Retrieving Similar Products in Software Product Lines

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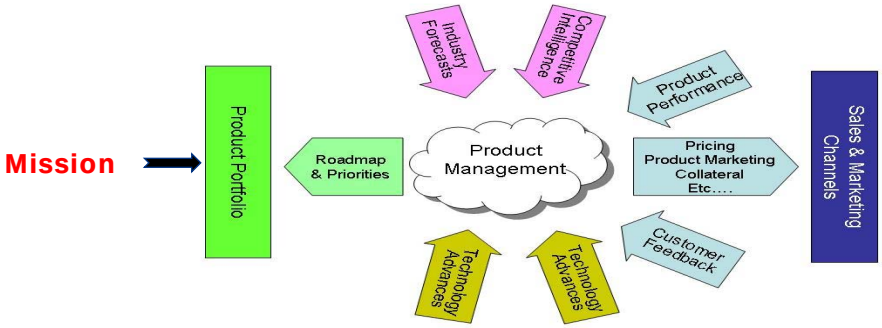
## What Products to Build ?

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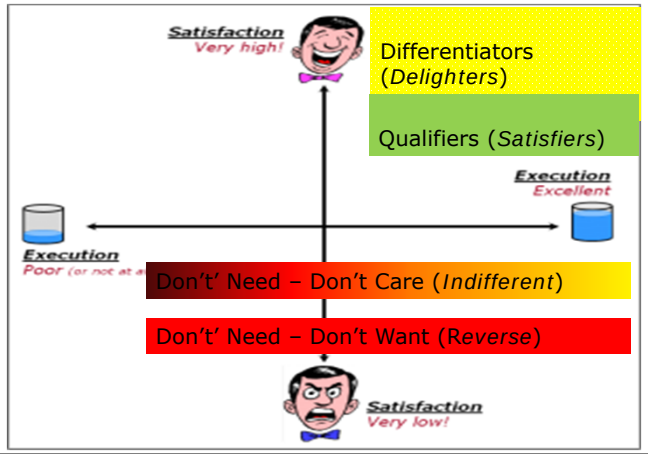
## Matching Supply & Demand (Kano Model)

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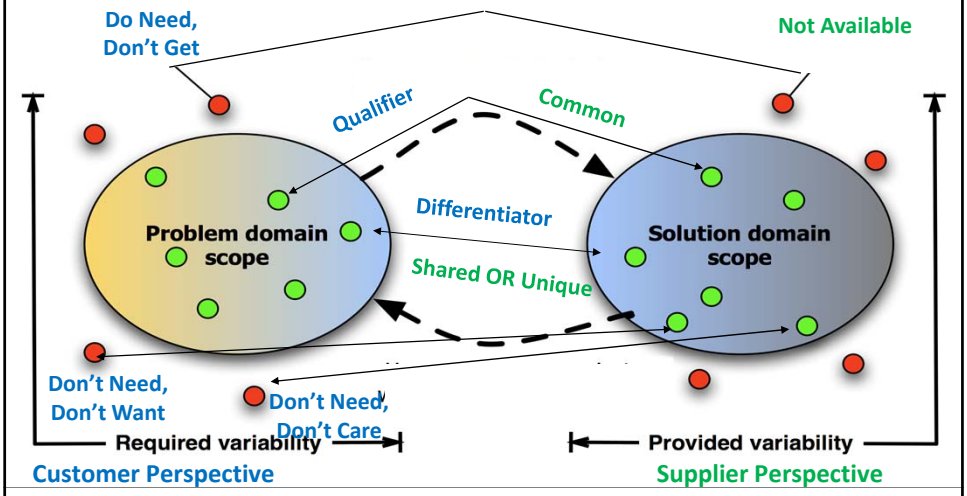
## Matching Supply & Demand

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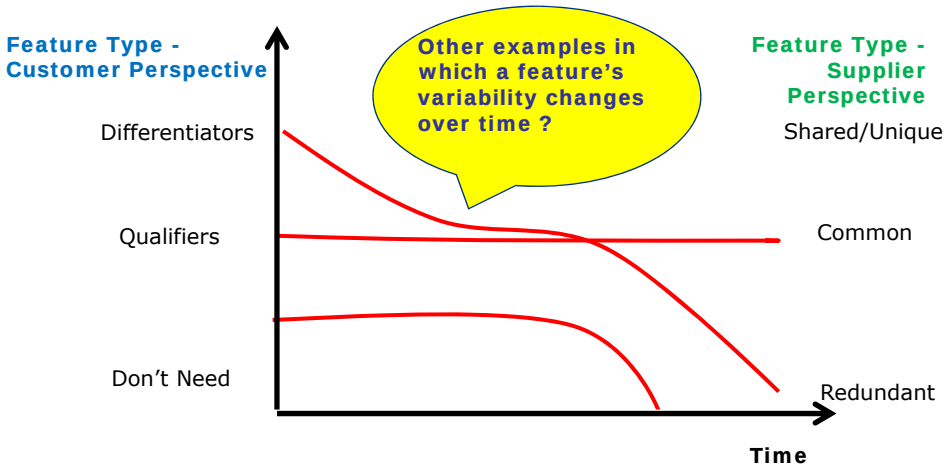
## Matching Supply & Demand - Feature Evolution

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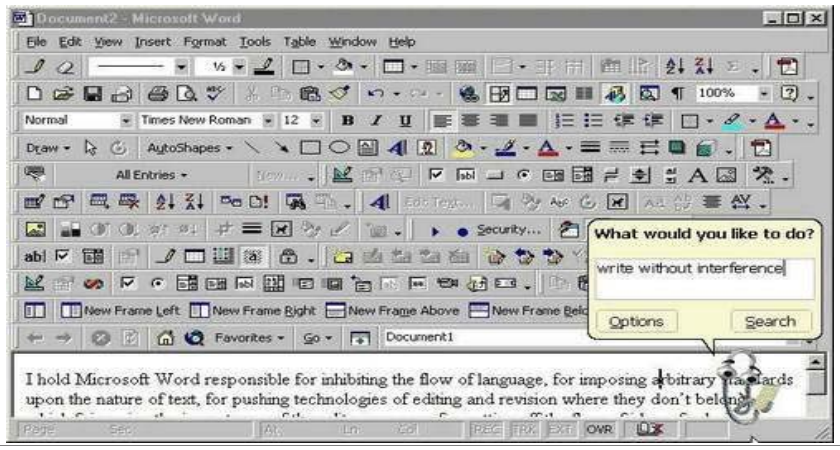
## Supply Trends – Sales-Driven Product Optimization ("Feature Creep")

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## Domain Platform Stretching

- Boeing 737 divided into 3 platforms:
- Initial (100,200)
- Classic (300,400,500)
- NextGen (600,700,800,900)

- Boeing 777 also been designed to be stretched


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## Motivation - Similarity

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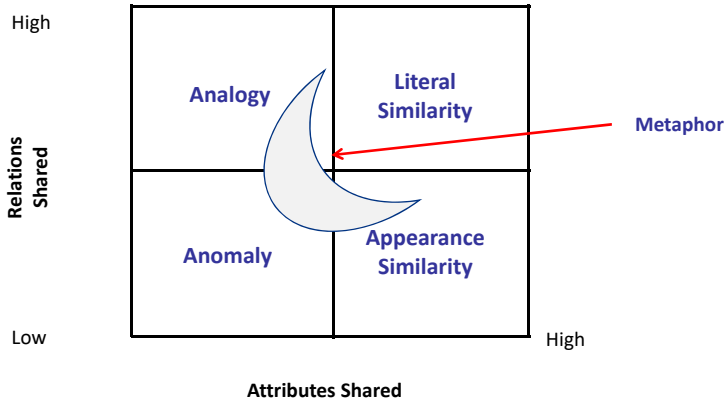
## Similarity

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## The Need for Similarity Support

- Compare existing products against partial target specification
- Compare similar features in different products
- Compare customer's perspective against supplier's perspectives
- Create a new product from ideas in other products

- What methods do we have ?

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# Part 2

- Feature Model Based Development

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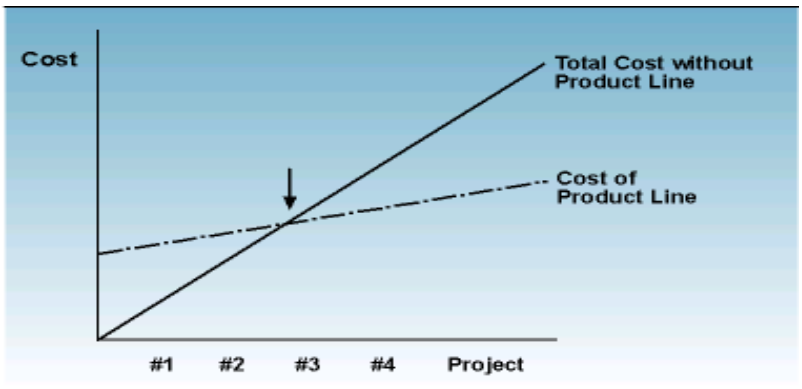
## Supply Trends - Product Lines

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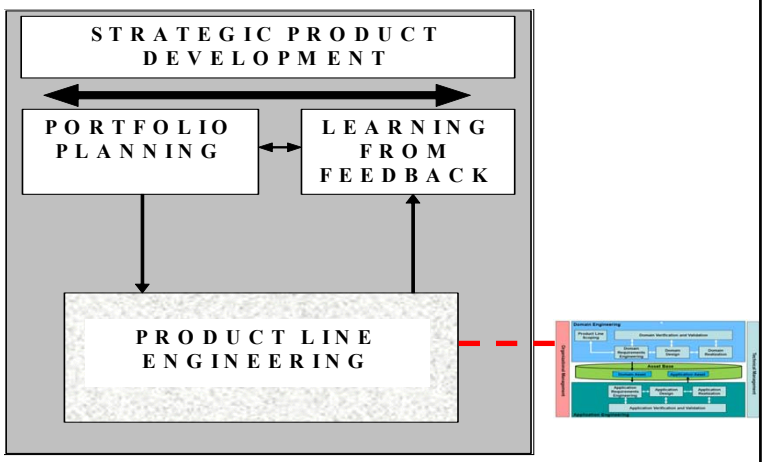
## Supply Trends – Product Line Development Framework

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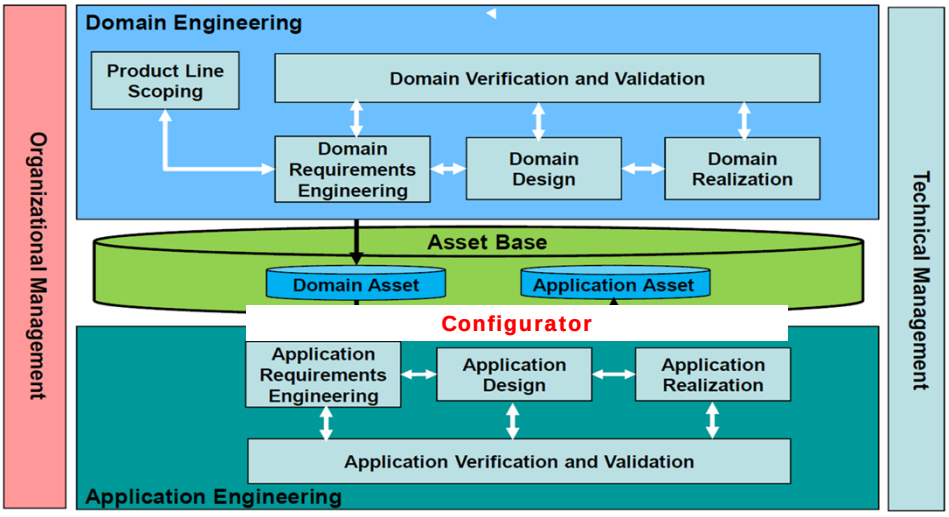
## Supply Trends - Product Line Engineering

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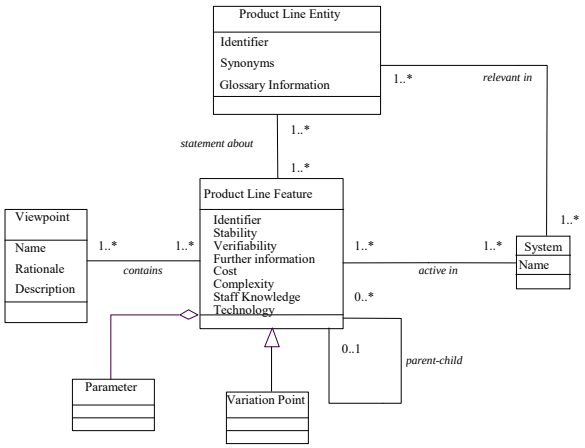
## Metamodel

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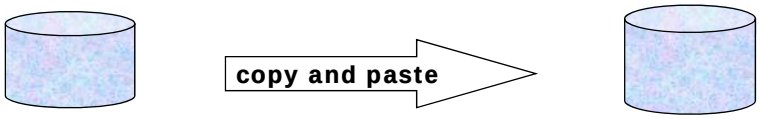
## Free Selection

- Free selection means allowing a single system requirements engineer (user) to browse a product line model and simply copy and paste a single requirement from anywhere in the model to the single system model.




Product Line Model Single System Model

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## Problems of Free Selection

- Selecting a single requirement is often not sufficient.
- Random choice can mean illegal choice
  - e.g. 2 mutually exclusive requirements
  - e.g. not choosing generic requirement.
- Untenable number of choices.
- BUT engineers like freedom of choice!!!

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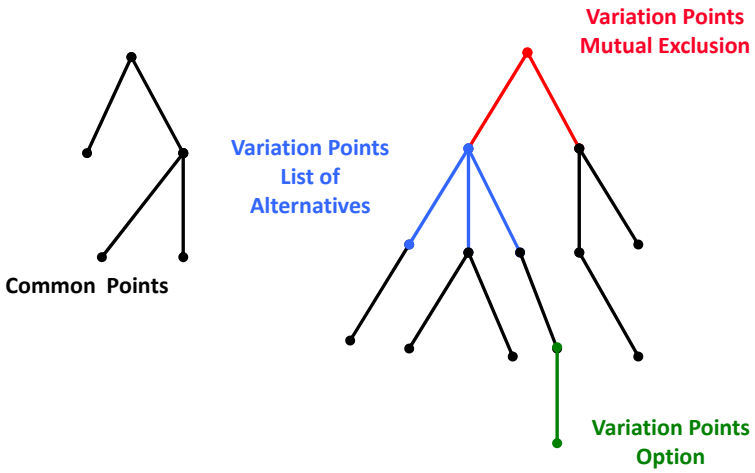
## Constraint-Based Selection

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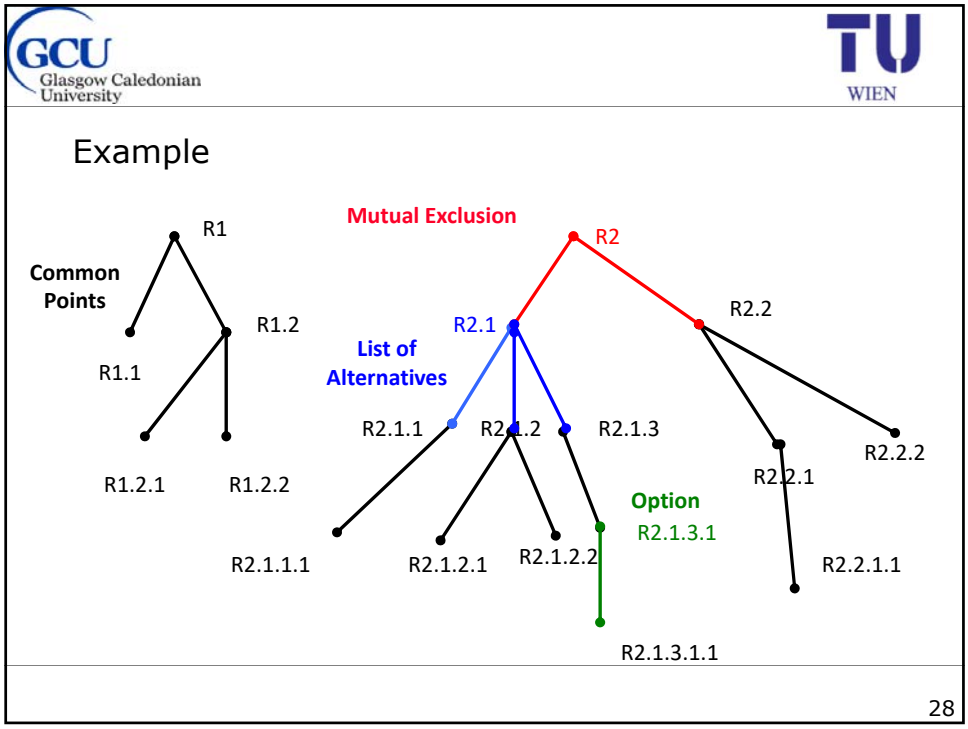
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Example
Common Points
R1
R1.1
R1.2
R1.2.1
R1.2.2
Mutual Exclusion
R2
R2.1
R2.2
List of Alternatives
R2.1.1
R2.1.2
R2.1.3
R2.2.1
R2.2.2
Option
R2.1.3.1
R2.1.1.1
R2.1.2.1
R2.1.2.2
R2.2.1.1
R2.1.3.1.1
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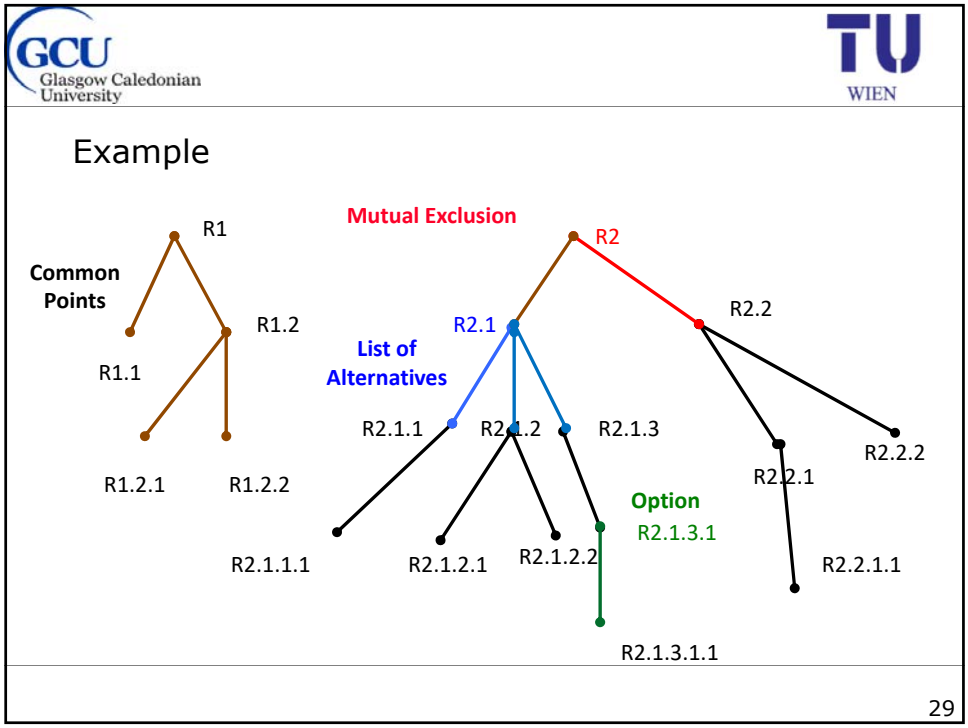
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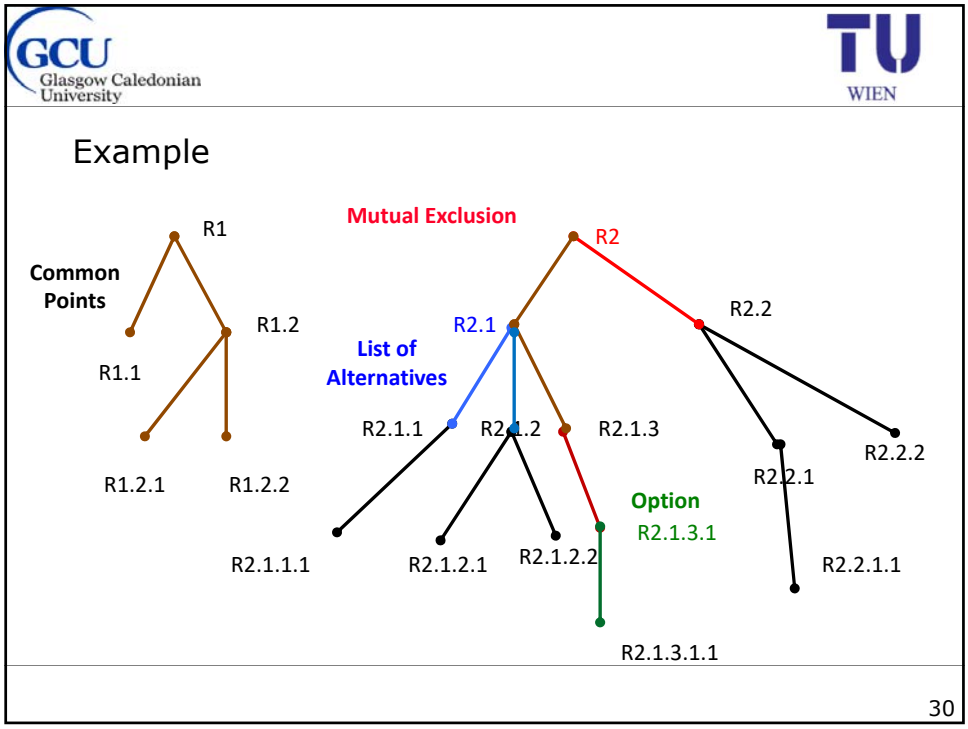
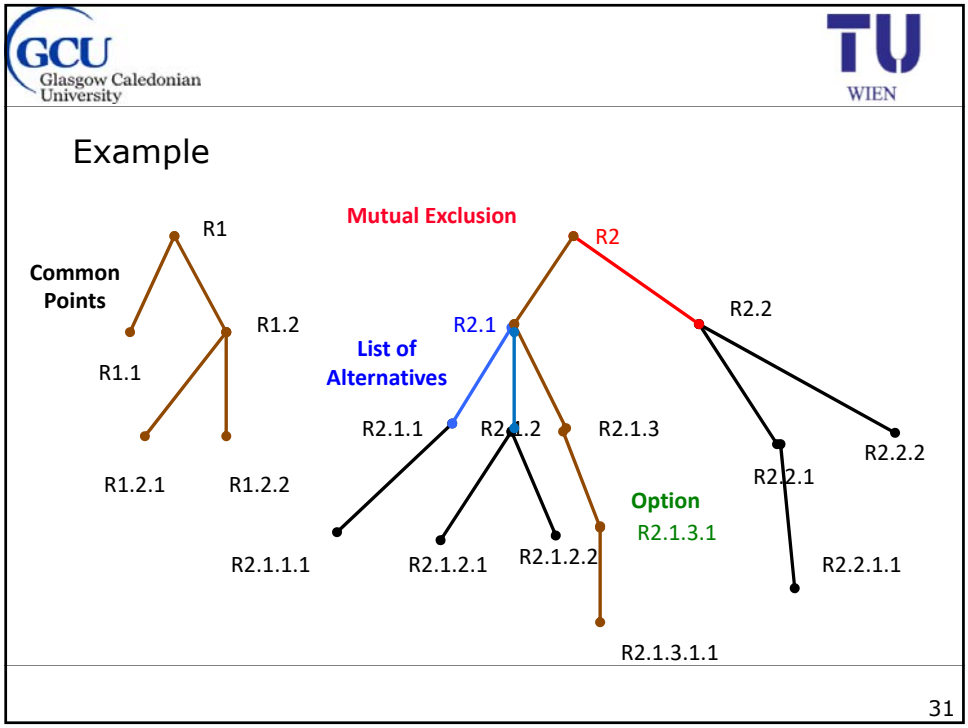
R2.1.2.1
R2.1.2.2
R2.2.1.1
R2.1.3.1.1
29



## Product Line Model using Formal Representations

- For a product line model P of product line requirements a logical expression can be defined as
  $E(P) = \{T_1 \wedge T_2 \wedge \ldots \wedge T_n \mid \{T_i = a_{i1}\ Я_{i1}\ a_{i2}\ Я_{i2}\ a_{i3}\ Я_{i3}\ \ldots\ Я_{i(n-1)}\ a_{in};\ a_{ij} = s(r_{ij})$
  - where $r_{ij}$ must be a directly reusable requirement or Variation Point;
  - and $Я_{ij} \in \{Я_{common}, Я_{mutex}, Я_{list\_alts}, Я_{option}\} \}$

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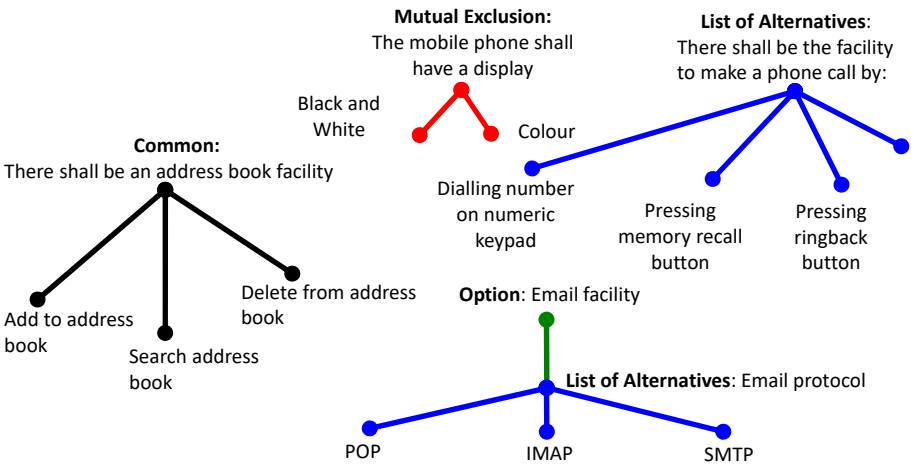
## Mobile Phone Example

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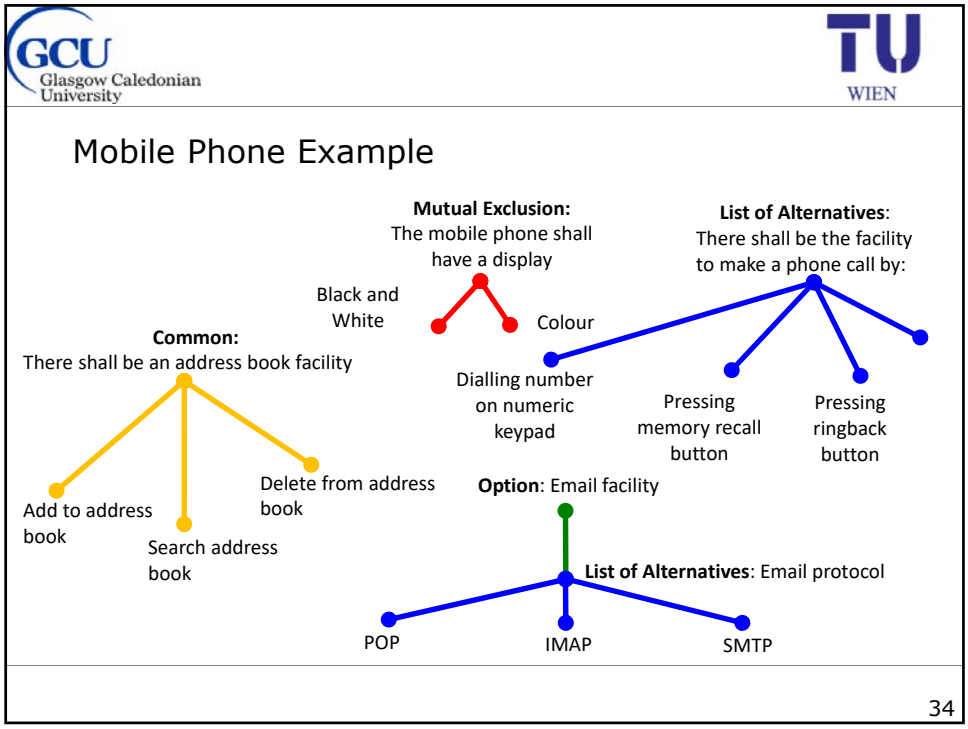


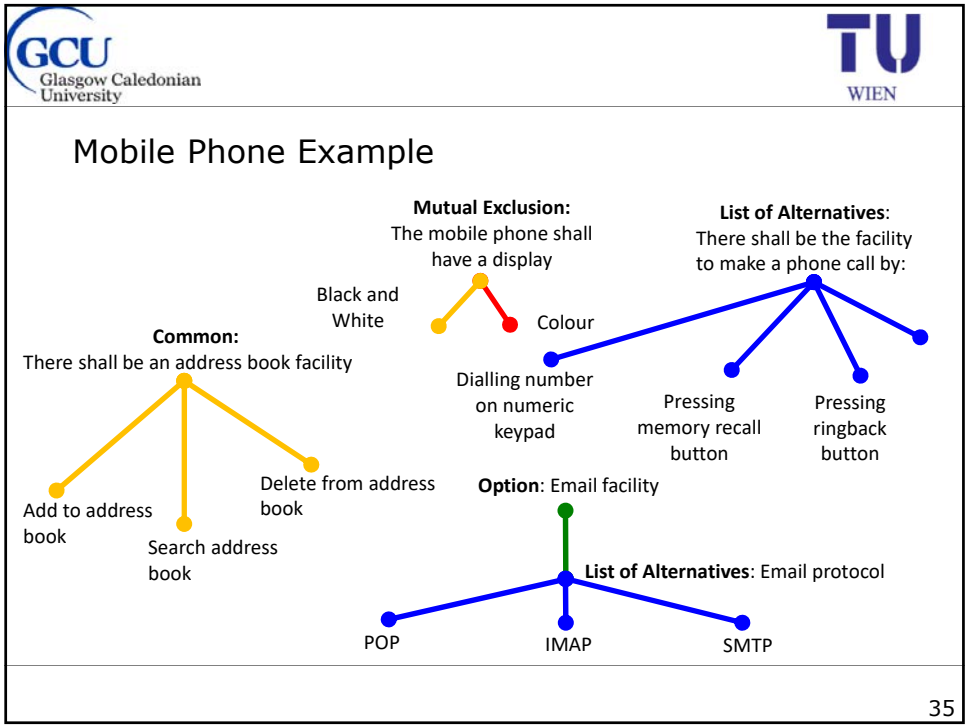

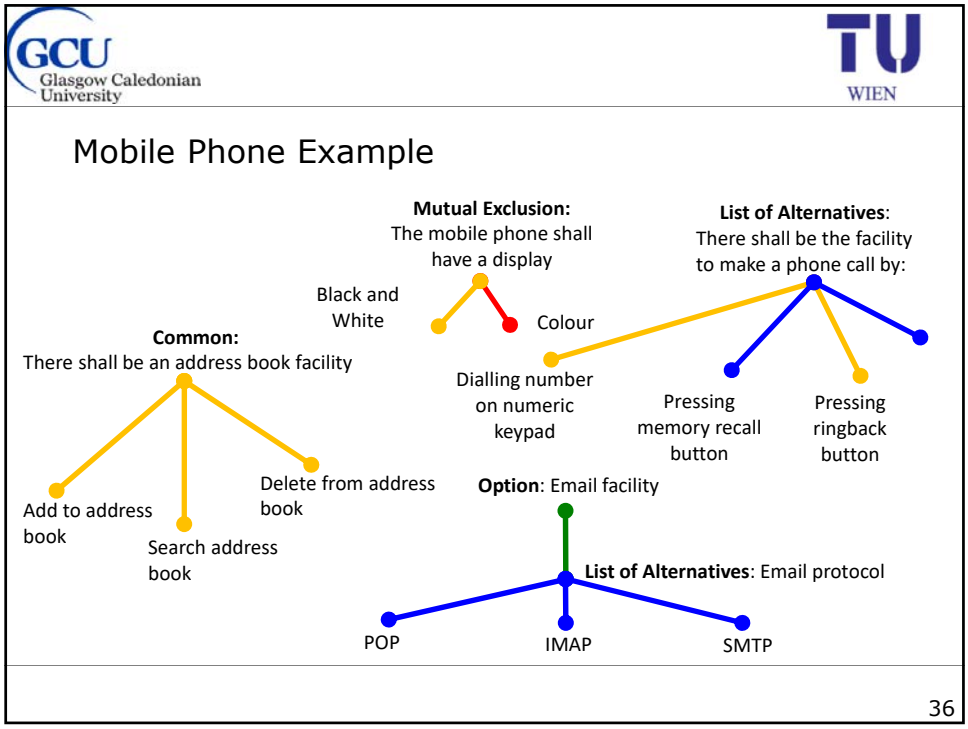


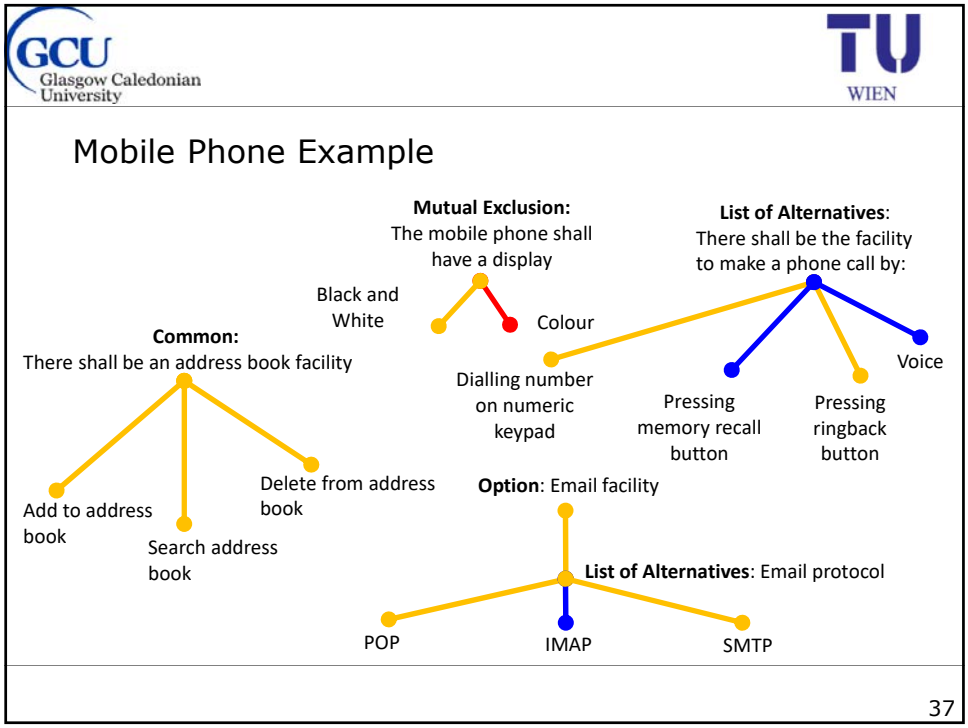

## Product Line Model using Formal Representations

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  - where $r_{ij}$ must be a directly reusable requirement or Variation Point;
  - and $Я_{ij} \in \{Я_{common}, Я_{mutex}, Я_{list\_alts}, Я_{option}\}\ \}$

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## Mobile Phone Example – Valid Selection

Propositional Logic Expression Evaluates to **TRUE** or **FALSE** depending on selections made.

New Product = $T_1 \wedge T_2 \wedge T_3 \wedge T_4$

((**AddressBook** $\wedge$ (**Add** $\wedge$ **Search** $\wedge$ **Delete**)) $\wedge$ .....($T_1$)
(**Display** $\wedge$ (**B&W** $\oplus$ **Colour**)) $\wedge$ .....($T_2$)
(**CallTypes** $\wedge$ (**Keypad** $\vee$ **Memory** $\vee$ **Ringback** $\vee$ **Voice**) $\wedge$ .....($T_3$)
(**Email** $\leftrightarrow$ (**EmailProtocol** $\wedge$ (**POP** $\vee$ **IMAP** $\vee$ **SMTP**))).....($T_4$)

i.e.

((**TRUE** $\wedge$ (**TRUE** $\wedge$ **TRUE** $\wedge$ **TRUE**)) $\wedge$ .....($T_1$)
(**TRUE** $\wedge$ (**TRUE** $\oplus$ **FALSE**)) $\wedge$ .....($T_2$)
(**TRUE** $\wedge$ (**TRUE** $\vee$ **FALSE** $\vee$ **TRUE** $\vee$ **FALSE**)) $\wedge$ .....($T_3$)
(**TRUE** $\leftrightarrow$ (**TRUE** $\wedge$ (**TRUE** $\vee$ **FALSE** $\vee$ **TRUE**))).....($T_4$)

which evaluates to **TRUE**

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## Mobile Phone Example – Invalid Selection

New Product = $T_1 \wedge T_2 \wedge T_3 \wedge T_4$

((AddressBook ∧ (Add ∧ Search ∧ **Delete**)) ∧ .....($T_1$)
(Display ∧ (B&W ⊕ **Colour**)) ∧ .....($T_2$)
(CallTypes ∧ (Keypad ∨ **Memory** ∨ Ringback ∨ **Voice**) ∧ .....($T_3$)
(Email ↔ (EmailProtocol ∧ (POP ∨ **IMAP** ∨ SMTP))).....($T_4$)

Not Selected

i.e.

((TRUE ∧ (TRUE ∧ TRUE ∧ FALSE)) ∧ .....($T_1$)
(TRUE ∧ (TRUE ⊕ FALSE)) ∧ .....($T_2$)
(TRUE ∧ (TRUE ∨ FALSE ∨ TRUE ∨ FALSE)) ∧ .....($T_3$)
(TRUE ↔ (TRUE ∧ (TRUE ∨ FALSE ∨ TRUE))).....($T_4$)

which evaluates to **FALSE because $T_1$ is FALSE**

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## Variation Point-Based Selection

- Use tree structure and Variation Points to direct requirements selection.
- Start at one of the roots.
- Traverse depth first.
- Ask user to make a choice at each Variation Point.
- Common requirements are automatically selected if their parents are already selected or if they are a root node.

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## Automated Feature Model Analysis

- Does the configured product satisfy the feature model constraints ?
- How many product configurations (if any) satisfy these constraints ?
- How many products satisfy a given set of features ?
- Any anomalies in the feature model e.g. contradictions, redundancy ?
- To what degree (expressed as a numeric value) has a feature model variable or common features.

**Feature models (regardless of notation) not suited to compare similarity.**

Benavides, D., Segura, S., Ruiz-Cortes, A., 2010 Automated Analysis of Feature Models 20 years Later: A Literature Review. *Information Systems*, 35(6):615–636.

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## Part 3

- Case-Based Reasoning

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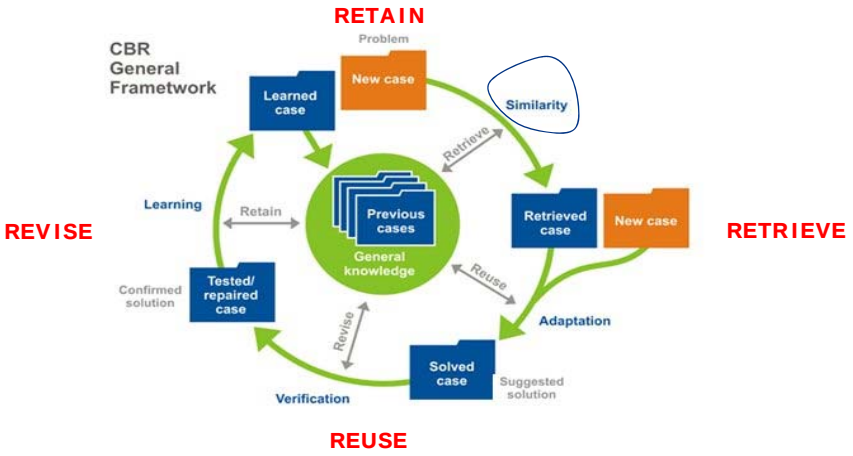
## Case-Based Reasoning




Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches, A Aamodt, E Plaza, AI Communications,Vol. 7 Nr. 1, March 1994, pp 39-59

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## CBR Characteristics

| Task | Issues |
|---|---|
| **RETAIN** | Concrete cases or Generalised cases;<br>Central knowledge units or distributed units<br>Indexed or flat or hierarchical<br>General and/or domain specific ontologies<br>Rich information beyond feature vectors |
| **RETRIEVE** | Use 1 or more similarity metrics e.g. K nearest Neighbour<br>Guided or not by deep model of general knowledge<br>Sequentially or in parallel |
| **REUSE** | Facilities to use directly or modified retrieved case |
| **REVISE** | Editing facilities to create a new "solved" case<br>(i) the end user does it OR<br>(ii) automated procedure: risk is that system makes poor judgement, yet it is added to the case-base which becomes progressively degraded. |

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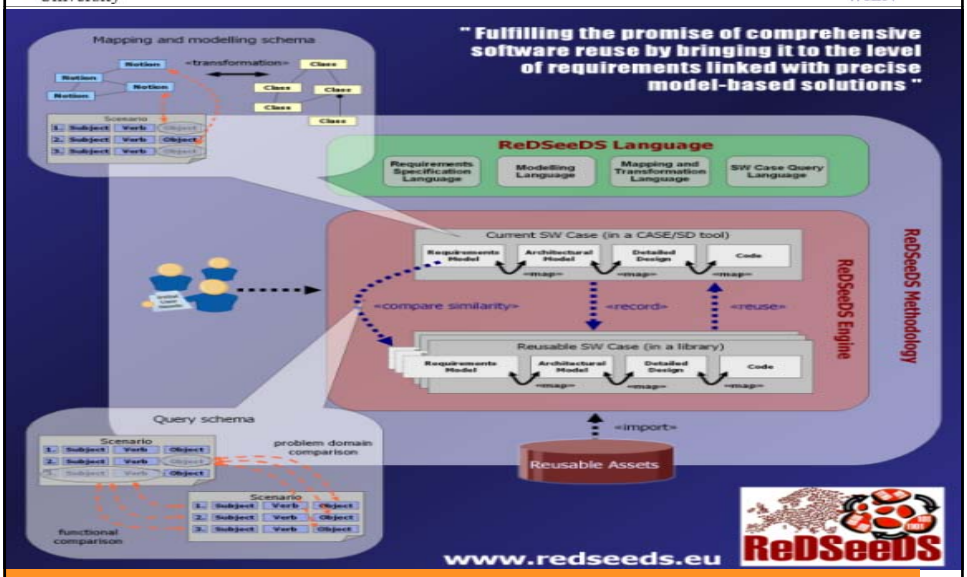
## CBR Example: ReDSeeDS




Version 0.7.0 released June 2016: Infovide S.A., Warsaw University of Technology (PL), HITeC e.V., University of Koblenz-Landau, Fraunhofer - Gesellschaft (Institute for Experimental Soft-ware Engineering), PRO DV Software AG (G), Institute of Mathematics and Computer Science, University of Latvia (LV), Vienna University of Technology (AU), Algoritmu sistemos,UAB (LT),

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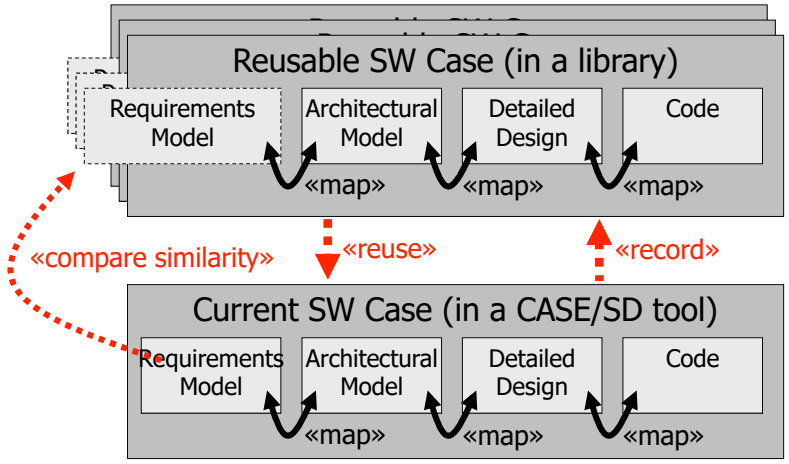
## RETAIN




Similarity-Driven Reuse, Bildhauer, D., Horn, T., Ebert, J., CSVM'09 17 May 2009

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## RETAIN


**Figure 1. Sample scenario written in RSL**

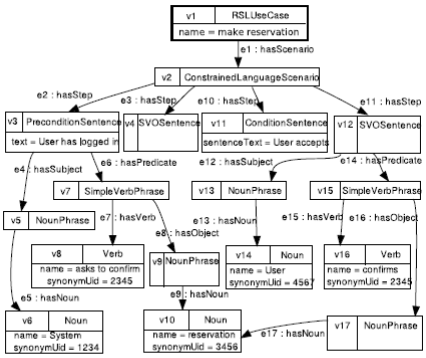


**Figure 2. Graph for the sample scenario**

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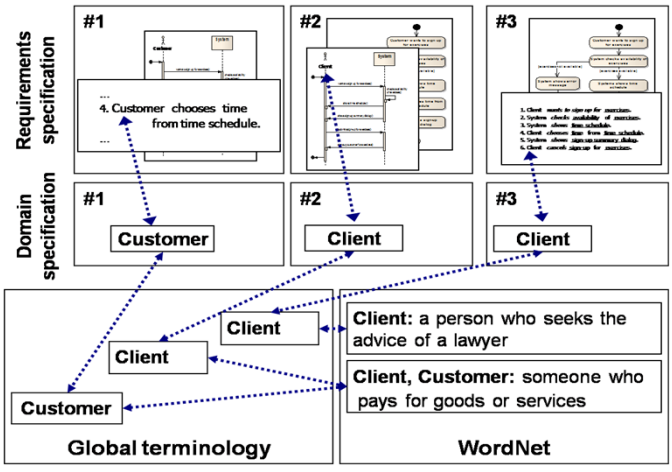
## RETAIN




https://wordnet.princeton.edu/

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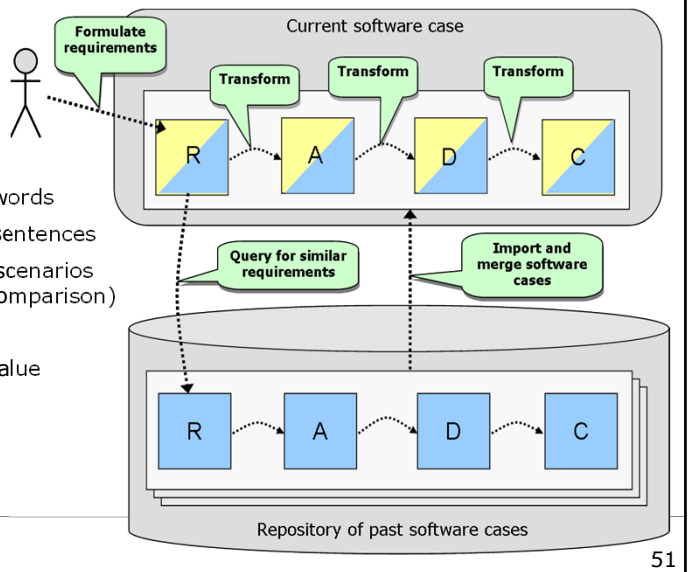
## RETRIEVE

- similarity between words
- similarity between sentences
- Similarity between scenarios (structured graph comparison)
- A single similarity value calculated

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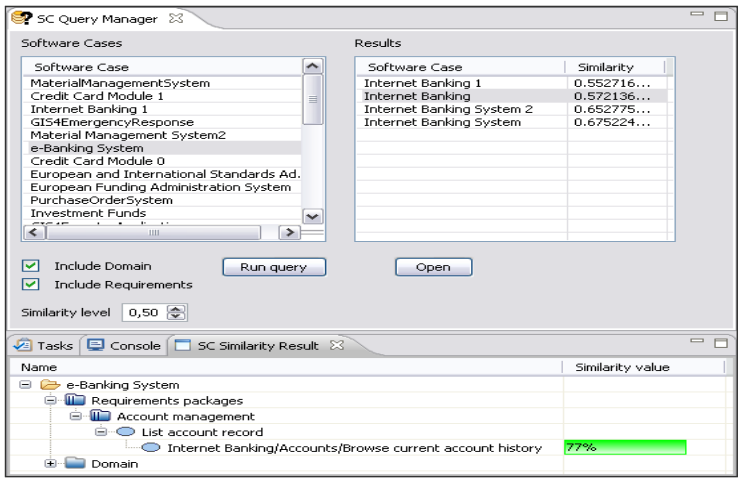
## RETRIEVE

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## REUSE & REVISE

- Select one of the better rated software cases.
- Import it to currently developed software case.
- May include design and implementation artefacts, but also requirements and domain descriptions.
- Merge reused case with currently developed one.

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## CBR Summary Characteristics

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# Part 4

- Similarity Matching in Software Product Line Development

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## Software Product Line Engineering v Case-Based Reasoning

| | Feature Modelling | Case-based Reasoning |
|---|---|---|
| **Model Structure Construction** | Complex | Straightforward in principle; But structural considerations can enhance search |
| **Model Content** | Detailed, Precise | Good-enough; supported by vocabularies Watch for poor old cases |
| **Product Derivation** | Constrained facilitated automated product derivation | Similar cases automatically retrieved. Monitor search performance & accuracy |
| **Costs of making *reusable*** | Substantial | Small but Adaptation Knowledge needed |
| **Benefits for *reuse*** | Facilitates automated product derivation | Facilitates finding similar cases for reuse |

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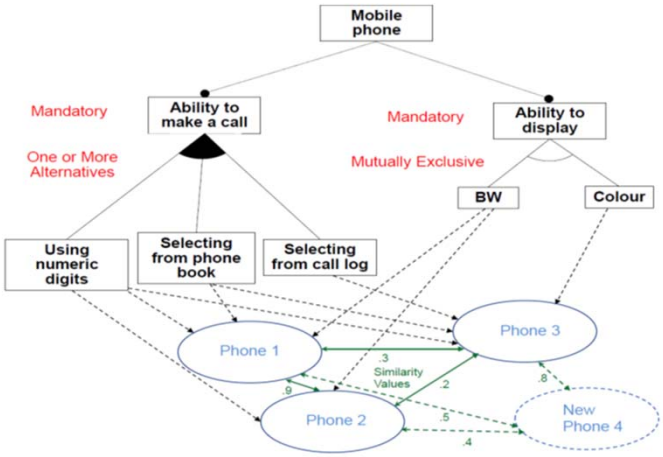
## Feature-Similarity Model




H. Kaindl and M. Mannion, A Feature-Similarity Model for Product Line Engineering, in *Proc. of the 14th International Conference on Software Reuse (ICSR'15)*, LNCS 8919, 2015, 34–41.

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## Construction Process

- Construct a feature model.
- Allocate features to products.
- Calculate similarity values between features.
- Calculate similarity values between specific feature combinations in different product specifications.
- Calculate similarity values between entire product specifications.

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## Exercise - Similarity in RE

| Task | Focus | Value of Similarity Matching ? |
|---|---|---|
| Product Line Scoping | Identify features that:<br>- distinguish the product line<br>- are important for target market<br>- Mark product line boundary. | ? |
| Domain Engineering | Specify the common and variable domain requirements of agreed product line | ? |
| Application Engineering | Generate or specify application specific requirements | ? |

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## Similarity in RE

| Task | Focus | Purpose of Similarity Matching |
|---|---|---|
| Product Line Scoping | Identify features that:<br>- distinguish the product line<br>- are important for target market<br>- Mark product line boundary. | Should product be in PL or not ?<br>If so, where to position it ? |
| Domain Engineering | Specify the common and variable domain requirements | Reduce model updates if similar requirements exist<br>Evaluate platforms before merger or separation |
| Application Engineering | Specify application specific requirements | Compare proposed product with existing products |

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- Summary & Conclusion

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## Motivation for Similarity

- Customers want to personalise
- Suppliers
  - want to be distinctive
  - want to be more efficient
- Match supply and demand

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## Research Challenges

- How can similarity matching be factored into existing process models for Product Line Scoping, Domain Engineering, and Application Engineering ?
- When to compute a similarity between two products: at product definition or on demand
- What are the thresholds for "similar" and for "different"?
- What are the thresholds for analogy anomaly ?
- Similarity Metrics
  - What combinations are worth computing e.g. pearson coefficient, cosine similarity, euclidean distance, k-nearest neighbour algorithm.
  - Use caution and prudence - best when used with data from other reference points.
  - Be clear on what you are using the metric for, get general agreement in the organization on which metrics to use, and focus on only a few metrics – less is more.

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## Selected Work of Presenters


- R. Hoch, H. Kaindl, R. Popp, D. Ertl, and H. Horacek, Semantic Service Specification for V&V of Service Composition and Business Processes, in *Proceedings of the 48nd Annual Hawaii International Conference on System Sciences (HICSS-48)*. Piscataway, NJ, USA: IEEE Computer Society Press, 2015.
- H. Kaindl and M. Mannion, A Feature-Similarity Model for Product Line Engineering, in *Proceedings of the 14th International Conference on Software Reuse (ICSR'15)*, LNCS 8919, 2015, 34–41.
- H. Kaindl, M. Smialek and W. Nowakowski, Case-based Reuse with Partial Requirements Specifications, in *Proceedings of the 18th IEEE International Requirements Engineering Conference (RE 2010)*, 2010, 399–400.
- H. Kaindl and D. Svetinovic, On confusion between requirements and their representations, *Requirements Engineering*, vol. 15, 2010, 307–311.
- M. Mannion and H. Kaindl, Using Parameters and Discriminants for Product Line Requirements. *Systems Engineering*, vol. 11, no. 1, 2008, 61–80.


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