Software Product Line Engineering

Variability Representation with Feature Models

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Definitions

Software product line engineering

"Software product line engineering (SPLE) refers to software engineering methods, tools and techniques for creating a ***collection of similar software systems*** *from a* ***shared set of software assets*** *using a* ***common means of production****."*

Van Vliet et al. - *Software engineering : principles and practice*, 1993

Software product line

"A software product line (SPL) is a set of software-intensive systems that share a common, managed set of features satisfying the specific needs of a ***particular market segment or mission*** *and that are developed from a* ***common set of core assets*** *in a* ***prescribed way****."*

Carnegie Mellon Software Engineering Institute - *http ://www.sei.cmu.edu/productlines/*

Software product line engineering

Software product line engineering

- Development paradigm to efficiently create and manage a **collection** of related software systems

  → Opposed to *single system development*

- Application of *mass customization* in the software engineering domain

3 important concepts

- Similar software systems
- Sharing software assets
- In a prescribed way

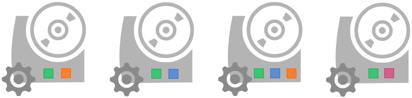
SPLE concepts (1/3)

Similar software systems

- Software systems from a **same domain** ...
  → Security, management, e-commerce, operating system, ...
- ... satisfying a **specific need** ...
  ✖ A schedule management software & a supplies management software
  ✔ Two antivirus softwares
- ... and sharing **commonalities**
  → Code, requirement, architecture...

SPLE concepts (2/3)

Sharing software assets



4 software systems and their common set of assets : 🟩 🟦 🟧 🟥

- Terminology : Asset / **feature** / functionality

  → an important caracteristic defined by domain experts to distinguish systems from one another

  → functional and non-functional aspects of a system

- Different **levels of granularity**

  → from low level code chunks to high level software functionalities

Asset's levels of abstraction

Different levels of abstraction of the shared assets

Example : A collection of e-commerce applications

- **High level** functionalities understandable by **final users**
  → payment methods, basket, newsletter, wishlist, ...
- **Low level** methods/algorithms implemented by **developers**
  → paypal authentication, connection to databases, form validation, ...

Why ?

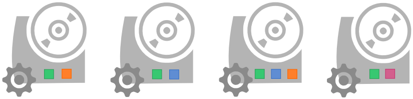
⇒ The basket functionality is implemented by several assets of lower level, but it is hidden from the user for understandability sake

⇒ A low level asset can be used in different high level functionalities (e.g., database connection)

SPLE concepts (2/3)

Sharing software assets

- **Commonalities** / **variabilities**



4 software systems and their common set of assets : 🟩 🟦 🟧 🟪

→ The *green* asset is present in all softwares

→ The *blue* and *orange* asset are shared by several softwares

→ The *purple* asset is specific to the fourth software

SPLE concepts (3/3)

In a prescribed way

- Documentation of what is common and what varies between the software systems

→ Defining the way assets vary/interact in the software systems

Example. A collection of e-commerce applications

→ All e-commerce application have a *catalog*

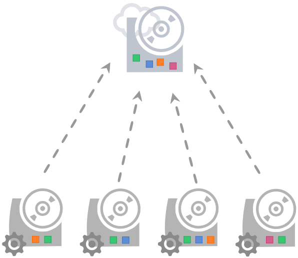
→ Some can optionally have a *wishlist* or a *newsletter* functionality

→ The *wishlist* functionality requires a *user account* management

⇒ **Organisation** of the set of assets in a **generic architecture**

SPLE concepts (3/3)

Generic architecture



→ The generic architecture permit to describe several related software systems depending on a set of assets

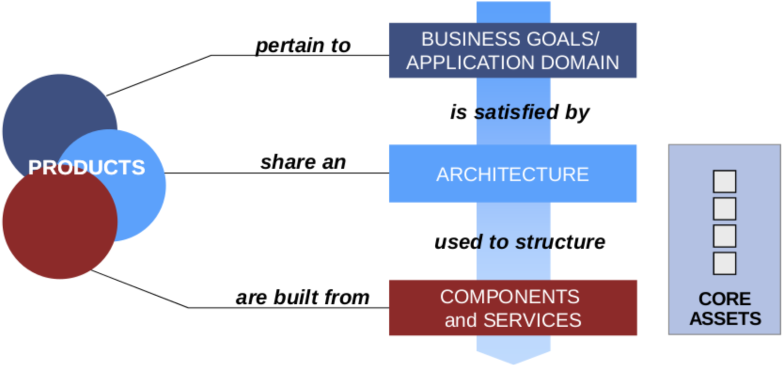
→ The set of software systems comply with the generic architecture

Why ?

⇒ **Factorisation and exploitation** of common assets

⇒ **Delimits the scope of a software family**

Synthesis



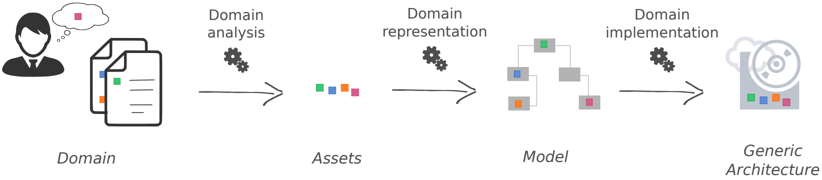
Carnegie Mellon Software Engineering Institute - *Patrick Donohoe*

⇒ Permits to **derive** several different software systems from the generic architecture

Domain engineering

Software produt line engineering - phase 1

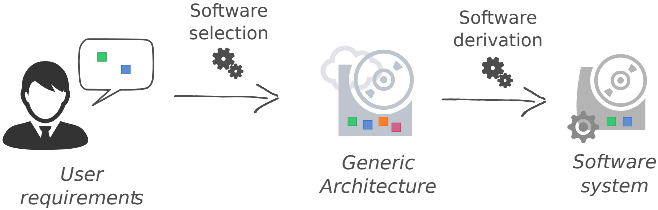
- **Domain engineering**
  - → Domain analysis
  - → Domain representation
  - → Domain implementation
  - ⇒ **Development FOR reuse**



Application engineering

Software produt line engineering - phase 2

- **Application engineering**
  - → Product selection
  - → Product derivation
  - ⇒ **Development BY reuse**



Software selection and software derivation

Software selection / configuration

- A user specifies its requirements = **configures** the architecture

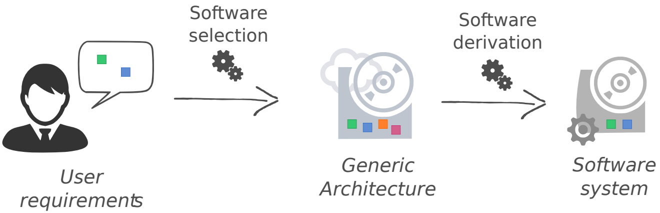
→ designate a product configuration

→ which has to comply with the architecture

Software derivation

- Implementation of the designated configuration

⇒ Leads to **(semi-)automated source code generation**



Benefits

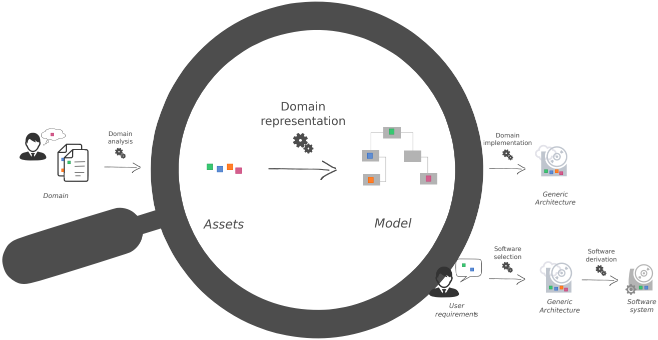
What are the benefits of software product line engineering ?

- Improved productivity by as much as 10×
- Increased quality by as much as 10×
- Decreased cost by as much as 60%
- Decreased labor needs by as much as 87%
- Decreased time to market (to field, to launch) by as much as 98%
- Ability to move into new markets in months, not years

Carnergie Mellon Software Engineering Institure - *http ://www.sei.cmu.edu/productlines/*

Benefits

Variability representation



Central point of SPLE

Modelisation of the common parts and variants contained in the software systems

= **variability** of the software product line

Variability models

Software product line variability representation

⇒ **Variability models**

Basis for SPLE operations and SPL management :

- Software selection
- Software derivation
- Product line evolution
- Information retrieval
- ...

How to represent the variability of a software product line ?

Variability modelling approaches

Several **variability modelling approaches** exist in the literature.

Two prevalent ones

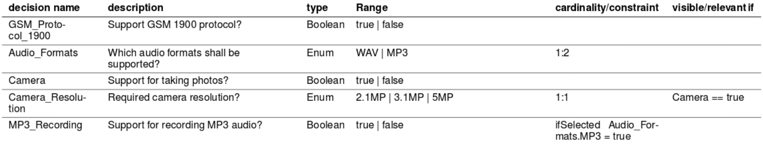
- Decision modelling
- Feature modelling

Decision modelling

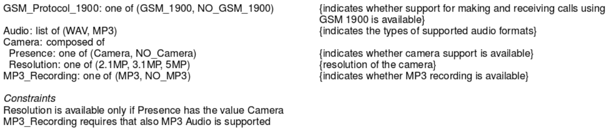
Decision modelling

→ List of possible decisions a user can make

→ *Focus on product selection/derivation*



decision name	description	type	Range	cardinality/constraint	visible/relevant if
GSM_Protocol_1900	Support GSM 1900 protocol?	Boolean	true | false		
Audio_Formats	Which audio formats shall be supported?	Enum	WAV | MP3	1:2	
Camera	Support for taking photos?	Boolean	true | false		
Camera_Resolution	Required camera resolution?	Enum	2.1MP | 3.1MP | 5MP	1:1	Camera == true
MP3_Recording	Support for recording MP3 audio?	Boolean	true | false	ifSelected Audio_Formats.MP3 = true	



```
GSM_Protocol_1900: one of (GSM_1900, NO_GSM_1900)     {indicates whether support for making and receiving calls using
                                                       GSM 1900 is available}
Audio: list of (WAV, MP3)                              {indicates the types of supported audio formats}
Camera: composed of
  Presence: one of (Camera, NO_Camera)                 {indicates whether camera support is available}
  Resolution: one of (2.1MP, 3.1MP, 5MP)               {resolution of the camera}
MP3_Recording: one of (MP3, NO_MP3)                    {indicates whether MP3 recording is available}

Constraints
Resolution is available only if Presence has the value Camera
MP3_Recording requires that also MP3 Audio is supported
```

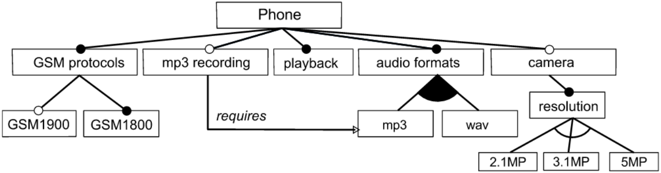
Czarnecki, Krzysztof, et al. “Cool features and tough decisions : a comparison of variability modeling approaches.”

Feature modelling

- **Feature modelling** (most prevalent one)

  → Distinguishable characteristics, dependencies

  → *Focus on domain representation*

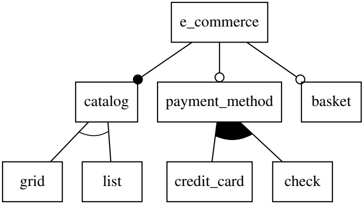


Czarnecki, Krzysztof, et al. "Cool features and tough decisions : a comparison of variability modeling approaches."

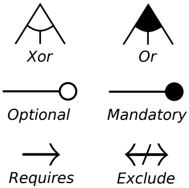
How to model SPL variability in terms of features ?

Feature models

Feature models



`payment_method` → `basket`
`basket` → `payment_method`

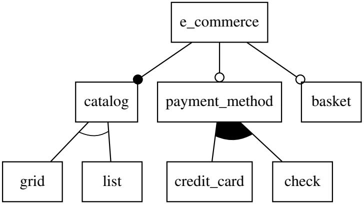


Feature models : family of visual **description languages**

→ permit to describe a finite set of features and dependencies between them

⇒ depict a finite set of valid combinations of features = **configurations**
(*1 configuration = 1 software system of the family*)

Feature tree



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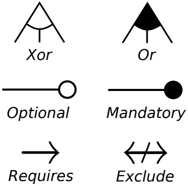
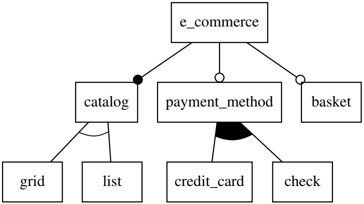


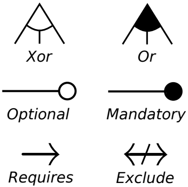
→ structure hierarchically the set of features in a tree = **feature tree**

- root feature = name of the modelised system
- (top to bottom) from most generalised features to most specialised one
- describe the system in several level of increasing details
- express **refinement relationships**

Software selection



payment_method → basket
basket → payment_method



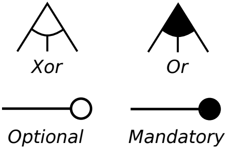
→ **Software selection**

- start from the root feature
- select feature from more generalised to more specialised ones (graph search)
- while respecting the expressed constraints

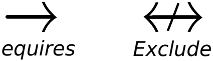
Constraints

→ **2 types of constraints**

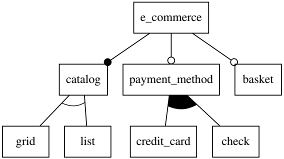
- graphical constraints expressed in the feature tree



- textual constraints which cannot be expressed in the tree : **cross-tree constraints**



Feature tree :



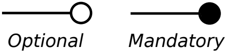
Cross-tree constraints :

```
payment_method → basket
basket → payment_method
```

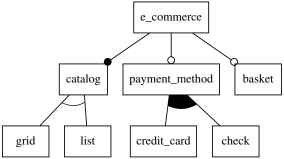
Graphical constraints (1)

→ **4 different "graphical constraints"** (1/2)

- between a parent feature and its child feature :



  - *Optional* : if the parent feature is selected, the child feature can be selected, or not
  - *Mandatory* : if the parent feature is selected, the child feature is necessarily selected

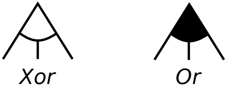


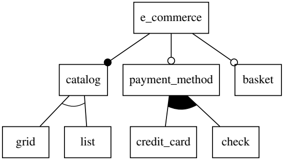
`payment_method` → `basket`
`basket` → `payment_method`

Graphical constraints (2)

→ **4 different "graphical constraints"** (2/2)

- between a parent feature and several of its child features :





`payment_method` → `basket`
`basket` → `payment_method`

  - *Or-group* : if the parent feature is selected, at least one feature involved in the group has to be selected
  - *Xor-group* : if the parent feature is selected, exactly one feature involved in the group has to be selected

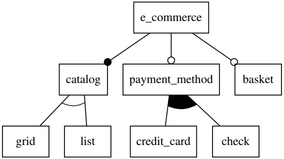
Textual constraints (2)

→ **2 different "textual constraints"**

- between two independant features :

$\longrightarrow$ *Requires* $\not\longleftrightarrow$ *Exclude*

  - *Requires* : if the premise is selected, the conclusion is also selected
  - *Exclude* : the two features are mutually exclusive



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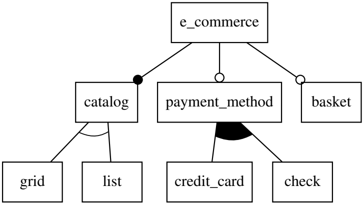
Feature models



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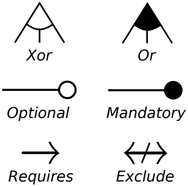


→ an e-commerce application necessarily possesses a catalog

→ this catalog can be displayed in a grid or in a list, but not both

→ it can eventually possess payment methods (credit card, check, or both)

→ it can also optionally have a basket

→ if the basket feature is selected, the application must possess at least one payment method (and conversely)

Feature model semantics

2 types of semantics

→ *what do feature models define ?*

- a *configuration* semantics / *logical* semantics
- an *ontological* semantics

Configuration/logical semantics

Configuration semantics :

→ *The list of valid configurations depicted by the feature model*

1. $\{e\_commerce, catalog, grid\}$
2. $\{e\_commerce, catalog, list\}$
3. $\{e\_commerce, catalog, grid, payment\_method, credit\_card, basket\}$
4. $\{e\_commerce, grid, payment\_method, check, basket\}$
5. $\{e\_commerce, catalog, grid, payment\_method, credit\_card, check, basket\}$
6. $\{e\_commerce, catalog, list, payment\_method, credit\_card, basket\}$
7. $\{e\_commerce, list, payment\_method, check, basket\}$
8. $\{e\_commerce, catalog, list, payment\_method, credit\_card, check, basket\}$

Ontological semantics

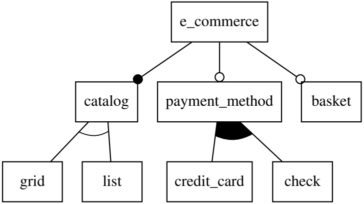
Ontological semantics

→ *Domain knowledge depicted by the feature model*

Example.

- *grid* and *list* refine *catalog*
- *catalog* and *payment_method* are two independent features
- *credit_card* and *check* are independent but can cohexist

Non-canonical representation



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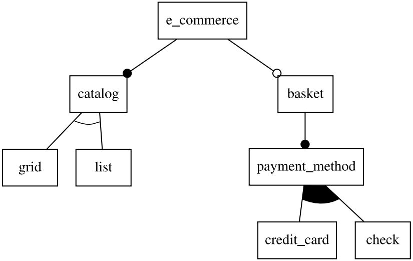
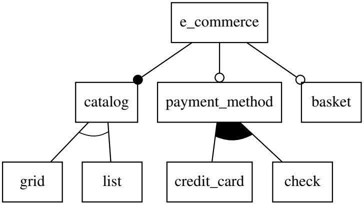


→ Same *configuration semantics*, but different *ontological semantics*

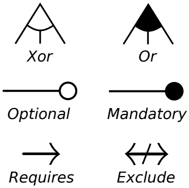
→ describe different domain knowledge

⇒ **Non-canonical** representation

Feature models



payment_method → basket
basket → payment_method



→ **understandable** and **compact** way to express variability

- *combinatorial explosion* of the possible software variants
- potentially large number of represented software systems

(*Example* : Linux SPL = 41 features = 2 × 10^7 configurations)

⇒ **enlarge the selection** of products offered