

# Model-based Software Product Lines Overview and Principles

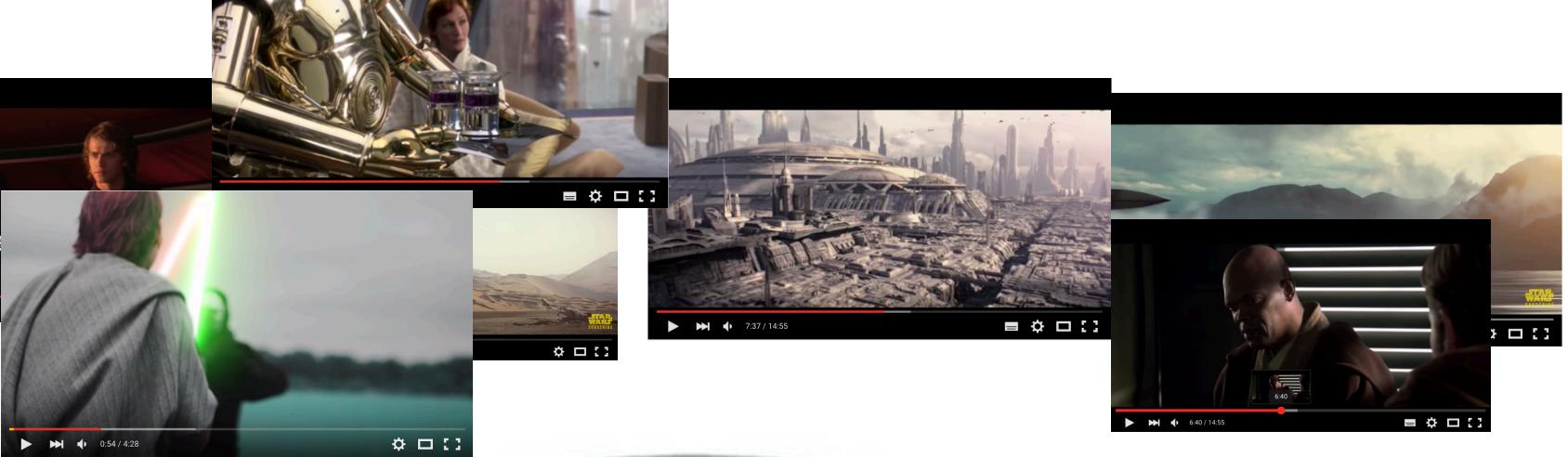
Mathieu Acher  
Maître de Conférences  
[mathieu.acher@irisa.fr](mailto:mathieu.acher@irisa.fr)

# Material

<https://github.com/acherm/teaching-MDE-MIAGE1819>

<http://teaching.variability.io>

<http://familiar.variability.io>





**Generator**  
~ composition of  
video sequences

**video  
variants**





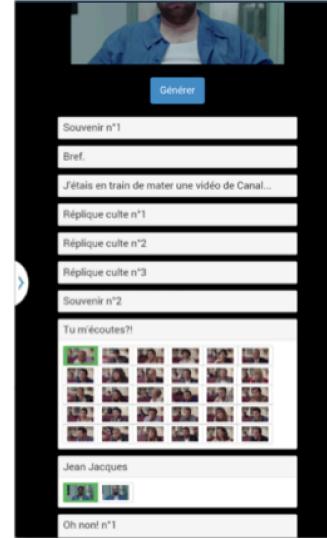
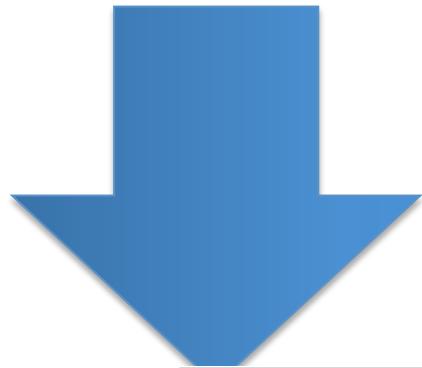
```

foo1.videogen ✎

mandatory videoseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"
optional videoseq v2 "v2Folder/v2.mp4"
alternatives v3 {
    videoseq v31 "v3/seq1.mp4"
    videoseq v32 "v3/seq1.mp4"
    videoseq v33 "v3/seq1.mp4"
}

alternatives v4 {
    videoseq v41 "v4/seq1.mp4"
    videoseq v42 "v4/seq1.mp4"
}
mandatory videoseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"

```



- ## Website/online
- Random generation
  - Configurator
  - Game
  - ...

foo1.videogen

```
mandatory videoseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"
optional videoseq v2 "v2folder/v2.mp4"
@alternatives v3 {
    videoseq v31 "v3/seq1.mp4"
    videoseq v32 "v3/seq1.mp4"
    videoseq v33 "v3/seq1.mp4"
}

@alternatives v4 {
    videoseq v41 "v4/seq1.mp4"
    videoseq v42 "v4/seq1.mp4"
}
mandatory videoseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"
```

**Feature model:** another model for modeling “features” of your Web site (eg ability to save the video; mode=generation with frequencies)

**configurable**  
**generator**  
**of video generator**

#### Website/online

- Random generation
- Configurator
- Game
- ...



## foo1.videoogen

```
mandatory videooseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"  
optional videooseq v2 "v2folder/v2.mp4"  
alternatives v3 {  
    videooseq v31 "v3/seq1.mp4"  
    videooseq v32 "v3/seq1.mp4"  
    videooseq v33 "v3/seq1.mp4"  
}  
  
alternatives v4 {  
    videooseq v41 "v4/seq1.mp4"  
    videooseq v42 "v4/seq1.mp4"  
}  
mandatory videooseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"
```

#1 How to design,  
create, and support  
dedicated languages  
(DSLs)?

#2 How to transform  
models/programs?



#3 How to manage  
variability/variants?

#4 How do frameworks  
internally work?

# Plan

- Rappel Ingénierie des Exigences
  - Septembre 2017
  - Software Product Line Engineering
  - Feature Models
    - Defacto standard for modeling product lines and variability
- VaryLaTeX case
- The Jhipster case
  - An example of a real-world highly configurable system: how it is implemented and how we can model/test JHipster

# Contract

- The idea of software product lines and variability
- Variability modeling
- Case studies

# Software Product Line and Variability Engineering

karoma - Poderosa

File Edit Console Tools Window Plug-in Help

Line feed CR Encoding iso-8859-1 generic

1 karoma 2 karoma

.config - Linux Kernel v2.6.33.3 Configuration

```
Processor type and features
Arrow keys navigate the menu. <Enter> selects submenus --->. Highlighted letters
are hotkeys. Pressing <> includes, <> excludes, <> modularizes features.
Press <Esc><Esc> to exit, <?> for Help, </> for Search. Legend: [*] built-in [ ] 
excluded <M> module capable <> module capable
```

[ ] Tickless System (Dynamic Ticks)  
[ ] High Resolution Timer Support  
[ ] Symmetric multi-processing support  
[ ] Support for extended (non-PC) x86 platforms  
[ ] Single-depth WCHAN output  
[ ] Paravirtualized guest support --->  
[ ] Memtest  
Processor family (Generic-x86-64) --->  
Preemption Model (No Forced Preemption (Server)) --->  
[ ] Reroute for broken boot IRQs (NEW)  
[ ] Machine Check / overheating reporting  
[ ] Dell laptop support  
[ ] /dev/cpu/microcode - microcode support  
[ ] /dev/cpu/\*/msr - Model-specific register support  
[ ] /dev/cpu/\*/cpuid - CPU information support  
Memory model (Sparse Memory) --->  
[\*] Sparse Memory virtual memmap (NEW)  
[ ] Allow for memory hot-add (NEW)  
[ ] Enable KSM for page merging  
(4096) Low address space to protect from user allocation  
[ ] Check for low memory corruption  
[ ] Reserve low 64K of RAM on AMI/Phoenix BIOSen  
-- MTRR (Memory Type Range Register) support  
[ ] MTRR cleanup support  
[ ] Enable seccomp to safely compute untrusted bytecode  
[ ] Enable -fstack-protector buffer overflow detection (EXPERIMENTAL)  
Timer frequency (250 HZ) --->  
[ ] kexec system call  
v(+)

<Select> < Exit > < Help >

# Kernel Linux





```
macher-wifi:getting-started macher1$ yo jhipster
```

I'm all done. Running `npm install & bower install` for you to install the required dependencies.

```
JHIPSTER GENERATOR
  JHipster
  JHipster
  JHipster
  JHipster
```

Welcome to the JHipster Generator v2.17.0

```
? (1/15) What is the base name of your application? jhipster
? (2/15) What is your default Java package name? com.mycompany.myapp
? (3/15) Do you want to use Java 8? Yes (use Java 8)
? (4/15) Which *type* of authentication would you like to use? (Use arrow keys)
> HTTP Session Authentication (stateful, default Spring Security mechanism)
  OAuth2 Authentication (stateless, with an OAuth2 server implementation)
  Token-based authentication (stateless, with a token)
```

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\$199.99\*

[Buy](#)

\$219.99\*

[Buy](#)

## Communication

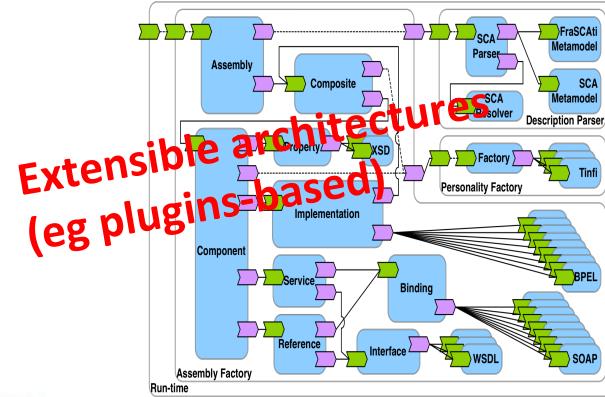
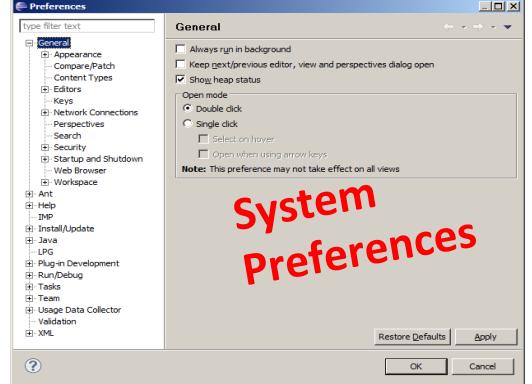
Bluetooth support	✓	✓	✓	✓
Join a homegroup	✓	✓	✓	✓
Internet Explorer 8	✓	✓	✓	✓
View Available Networks	✓	✓	✓	✓
Windows Connect Now (WCN)	✓	✓	✓	✓
Create a homegroup		✓	✓	✓
Location and other sensors support		✓	✓	✓
Support for joining domains			✓	✓

## Entertainment

DirectX 11	✓	✓	✓	✓
Gadgets	✓	✓	✓	✓
Games Explorer	✓	✓	✓	✓
Play To	✓	✓	✓	✓
Windows Media Player 12	✓	✓	✓	✓
Create and play DVDs		✓	✓	✓
Internet TV		✓	✓	✓

NEW KANGOO VAN RANGE

Configurators



# External Variability Internal Variability Variability @ run.time

[httpd.conf](http://httpd.conf) -- win32 Apache  
Building a Web Server, for Windows

```
Listen 80
ServerRoot "/www/Apache2"
DocumentRoot "/www/webroot"

ServerName localhost:80
ServerAdmin admin@localhost

ServerSignature On
ServerTokens Full

DefaultType text/plain
AddDefaultCharset ISO-8859-1
UseCanonicalName Off

HostnameLookups Off

ErrorLog logs/error.log
LogLevel error

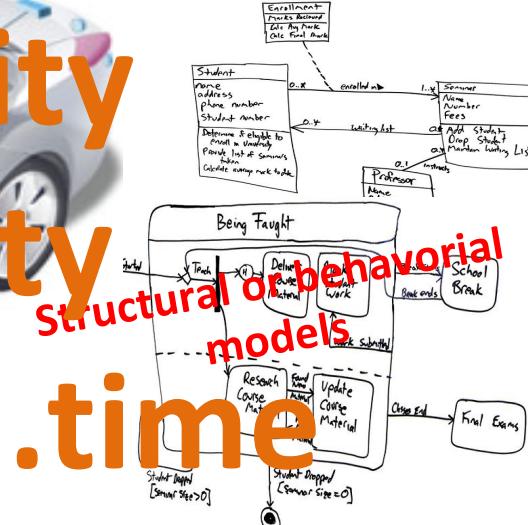
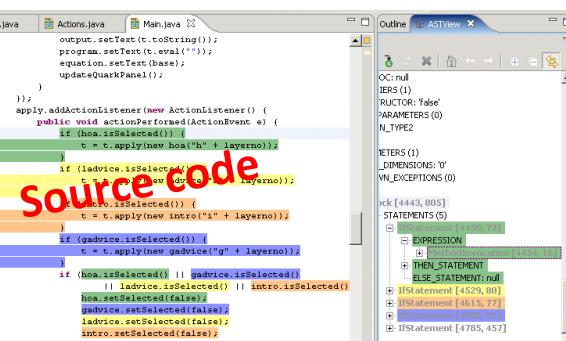
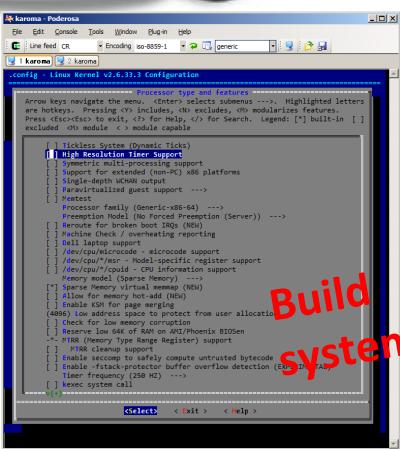
PidFile logs/httpd.pid

Timeout 300

KeepAlive On
MaxKeepAliveRequests 100
KeepAliveTimeout 15

<IfModule mpm_winnt.c>
    ThreadsPerChild 250
    MaxRequestsPerChild 0
</IfModule>
```

Configuration files





(a) Variant #1 of video sequence



(b) Variant #2 of video sequence



(c) Variant #3 of video sequence



(d) Variant #4 of video sequence



(e) Variant #5 of video sequence



(f) Variant #6 of video sequence

Figure 1: Six variants of video sequences synthesized with ViViD

```
/* [Customize body] */

//Set the outside length of your pencil box.
length=190;//[70:400]
//Set the outside depth of your pencil box.
depth=70;//[50:400]
//Set the total height of your pencil box. The top of the box is set at 15mm.
//Extra height is added to the body section.
height=40;//[40:150]
```

1

//Choose divider orientation. Long is for the X direction.

long = 1;//[0,1,2]

//Short is for the Y direction.

short = 2;//[0,1,2,3]

//When you have 2 long dividers,

// picking yes here will put short dividers in the center section.

center = 0;//[1:Yes,0>No]

[Lid inside settings](#)

[Lid inside content](#)

[Lid outside](#)

[Customize body](#)

[Design key](#)

[Customize ruler](#)

[Printer platform se](#)

**Length** Set the outside length of your pencil box. 190

**Depth** Set the outside depth of your pencil box. 70

**Height** Set the total height of your pencil box. The top of the box is set at 15mm. Extra height is added to the body section. 40

**Long** Choose divider orientation. Long is for the X direction.

**Short** Short is for the Y direction.

**Center** When you have 2 long dividers, picking yes here will put short dividers in the center section.

### Customizable Battery Case

by water, published Mar 5, 2013



[Thing Info](#)

[Instructions](#)

[Thing Files](#)

20  
Comments

8  
Made

473  
Collections

366  
Remixes

#### Description

A customizable battery case to hold batteries while traveling. Configurable for the number of batteries and type (as long as they're cylindrical). This is a updated version of the customizable battery carrier ([thingiverse.com/thing:51376](#)), re-designed to work without magnets as requested by GregFisk25.

20865 2444

Found in Containers

Report Thing as Inappropriate

Makes

view more >

Customize body
Design key
Customize ruler
Printer platform se

▲
◀
▶
▼

Bref

bref.  
CANAL à 30 ans.

ETAPE 1 : DONNE TON PRENOM

MATHIEU

→ OK

# Online Generator

bref30ans.canalplus.fr/#c

## **ÉTAPE 2 : CHOISIS 3 BONS SOUVENIRS**



# Variant



A large, intricate 3D white maze is set against a light gray background. The maze consists of many interconnected paths and dead ends, creating a complex network of levels and corners. It occupies the entire frame, from the top left to the bottom right.

**Variability = Complexity**

# 33 features



a unique variant for every  
person on this planet

optional, independent

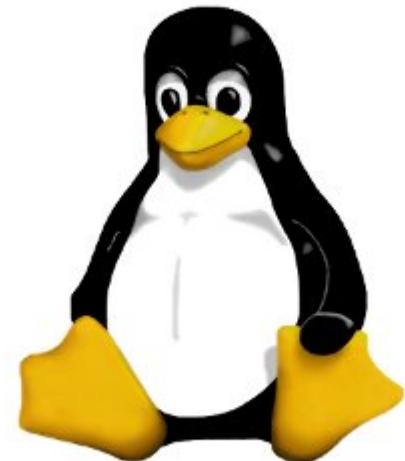
320<sup>optional, independent</sup>  
features

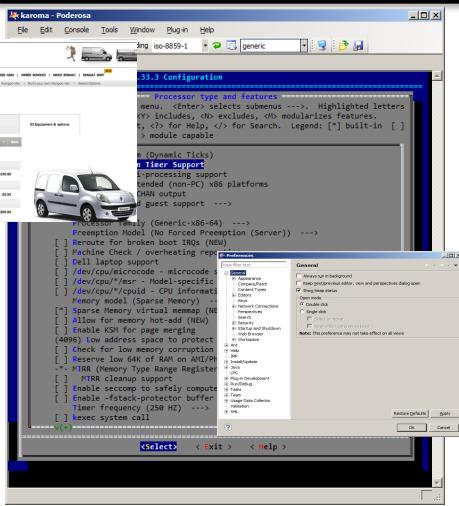
more variants than estimated  
atoms in the universe



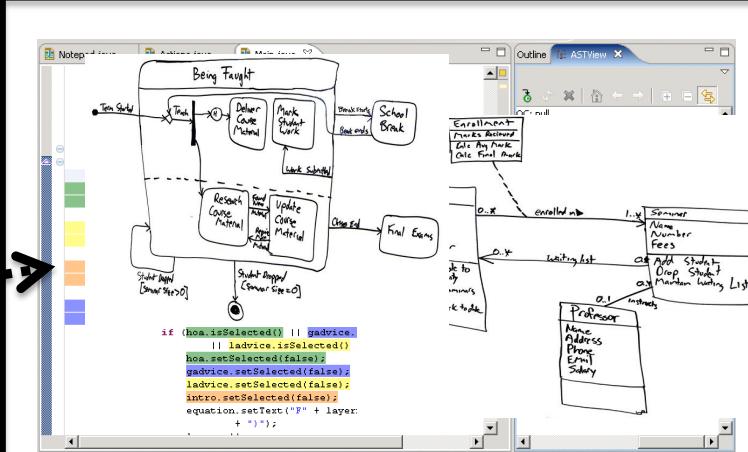
2000 features

10000  
features





**Variability Abstraction Model (VAM)**



**Variability Realization Model (VRM)**

**Domain Artefacts (e.g., models)**



**Configuration**  
(resolution model)



**Software Generator**  
(derivation engine)



[generator-jhipster / app / templates / src / main / java / package / config / \\_DatabaseConfiguration.java](#) **jdubois** 2 days ago Use Spring Boot's configuration meta-data9 contributors 

184 lines (165 sloc) | 9.69 KB

[Raw](#) [Blame](#) [History](#)   

```
1 package <%=packageName%>.config;
2 <% if (databaseType == 'sql') { %>
3 import <%=packageName%>.config.liquibase.AsyncSpringLiquibase;
4 import com.codahale.metrics.MetricRegistry;
5 import com.fasterxml.jackson.datatype.hibernate4.Hibernate4Module;
6 import com.zaxxer.hikari.HikariConfig;
7 import com.zaxxer.hikari.HikariDataSource;
8 import liquibase.integration.spring.SpringLiquibase;<% } %><% if (databaseType == 'mongodb' && authenticationType == 'oauth2') { %>
9 import <%=packageName%>.config.oauth2.OAuth2AuthenticationReadConverter;<% } %><% if (databaseType == 'mongodb') { %>
10 import com.mongodb.Mongo;
11 import org.mongeez.Mongeez;<% } %>
12 import org.slf4j.Logger;
13 import org.slf4j.LoggerFactory;<% if (databaseType == 'sql') { %><% if (hibernateCache == 'hazelcast') { %>
14 import org.springframework.cache.CacheManager;<% } %>
15 import org.springframework.beans.factory.annotation.Autowired;
16 import org.springframework.boot.autoconfigure.condition.ConditionalOnExpression;<% } %><% if (databaseType == 'mongodb') { %>
17 import org.springframework.boot.autoconfigure.mongo.MongoAutoConfiguration;
18 import org.springframework.boot.autoconfigure.mongo.MongoProperties;<% } %><% if (databaseType == 'sql') { %>
19 import org.springframework.boot.autoconfigure.jdbc.DataSourceProperties;
20 import org.springframework.boot.autoconfigure.liquibase.LiquibaseProperties;
21 import org.springframework.context.ApplicationContextException;<% } %>
22 import org.springframework.context.annotation.Bean;
23 import org.springframework.context.annotation.Configuration;
24 import org.springframework.context.annotation.Profile;<% if (databaseType == 'mongodb') { %>
25 import org.springframework.context.annotation.Import;<% } %><% if (databaseType == 'sql') { %>
26 import org.springframework.core.env.Environment;<% } %><% if (databaseType == 'mongodb' && authenticationType == 'oauth2') { %>
27 import org.springframework.core.convert.converter.Converter;<% } %><% if (databaseType == 'mongodb') { %>
28 import org.springframework.core.io.ClassPathResource;<% } %><% if (searchEngine == 'elasticsearch') { %>
29 import org.springframework.data.elasticsearch.repository.config.EnableElasticsearchRepositories;<% } %><% if (databaseType == 'mon
30 import org.springframework.data.mongodb.config.AbstractMongoConfiguration;
31 import org.springframework.data.mongodb.config.EnableMongoAuditing;<% } %><% if (databaseType == 'mongodb' && authenticationType =
32 import org.springframework.data.mongodb.core.convert.CustomConversions;<% } %><% if (databaseType == 'mongodb') { %>
33 import org.springframework.data.mongodb.core.mapping.event.ValidatingMongoEventListener;
34 import org.springframework.data.mongodb.repository.config.EnableMongoRepositories;
35 import org.springframework.validation.beanvalidation.LocalValidatorFactoryBean;<% } %><% if (databaseType == 'sql') { %>
```

macher-wifi:getting-started macher1\$ yo jhipster

I'm all done. Running `npm install & bower install` for you to install the required dependencies.

# JHIPSTER STACKER FOR JAVA EDIENS

Welcome to the JHipster Generator v2.17.0

- ? (1/15) What is the base name of your application? `jhipster`
- ? (2/15) What is your default Java package name? `com.mycompany.myapp`
- ? (3/15) Do you want to use Java 8? Yes (use Java 8)
- ? (4/15) Which \*type\* of authentication would you like to use? (Use arrow keys)
  - > `HTTP Session Authentication (stateful, default Spring Security mechanism)`
  - `OAuth2 Authentication (stateless, with an OAuth2 server implementation)`
  - `Token-based authentication (stateless, with a token)`

## Variability Model



mapping

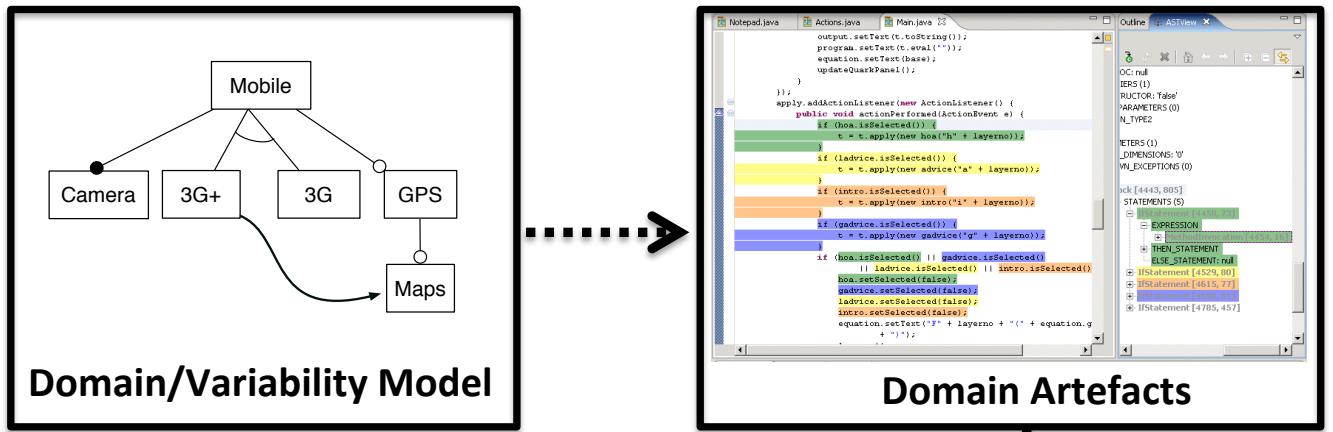
A screenshot of a GitHub repository page for 'generator-jhipster'. The file 'DatabaseConfiguration.java' is shown with 184 lines of code. The code is heavily annotated with conditionals like `%><% if (databaseType == 'sql') { %>` and imports for various database and security configurations. A large black arrow points from the 'Variability Model' box to this code block, labeled 'mapping'.

```
1 package io.jhipster.app.templates/src/main/java/package/config/_DatabaseConfiguration.java
2
3 import ckpackagegenx0.config.SpringLiquibase;
4 import com.codahale.metrics.MetricRegistry;
5 import com.fasterxml.jackson.datatype.hibernate4.Hibernate4Module;
6 import com.zaxxer.hikaricp.HikaricpConfig;
7 import com.zaxxer.hikaricp.HikaricpDataSource;
8 import org.springframework.boot.autoconfigure.spring.SpringLiquibase;
9 import org.springframework.boot.autoconfigure.security.oauth2.OAuth2AuthenticationConverter;
10 import org.springframework.boot.autoconfigure.mongo.MongoAutoConfiguration;
11 import org.springframework.boot.autoconfigure.mongo.MongoProperties;
12 import org.slf4j.Logger;
13 import org.slf4j.LoggerFactory;
14 import org.springframework.beans.factory.annotation.Autowired;
15 import org.springframework.boot.autoconfigure.condition.ConditionalOnExpression;
16 import org.springframework.boot.autoconfigure.mongo.MongoAutoConfiguration;
17 import org.springframework.boot.autoconfigure.mongo.MongoProperties;
18 import org.springframework.boot.autoconfigure.mongo.MongoProperties;
19 import org.springframework.boot.autoconfigure.mongo.MongoProperties;
20 import org.springframework.boot.autoconfigure.mongo.liquibase.LiquibaseProperties;
21 import org.springframework.boot.autoconfigure.liquibase.LiquibaseProperties;
22 import org.springframework.boot.context.ApplicationContextException;
23 import org.springframework.context.annotation.Bean;
24 import org.springframework.context.annotation.Configuration;
25 import org.springframework.context.annotation.Profile;
26 import org.springframework.context.annotation.Import;
27 import org.springframework.core.convert.converter.Converter;
28 import org.springframework.core.io.ClassPathResource;
29 import org.springframework.data.elasticsearch.repository.config.EnableElasticsearchRepositories;
30 import org.springframework.data.mongodb.config.AbstractMongoConfiguration;
31 import org.springframework.data.mongodb.config.EnableMongoAuditing;
32 import org.springframework.data.mongodb.core.mapping.event.ValidatingMongoEventListener;
33 import org.springframework.data.mongodb.repository.config.EnableMongoRepositories;
34 import org.springframework.validation.beanvalidation.LocalValidatorFactoryBean;
35 import org.springframework.validation.beanvalidation.LocalValidatorFactoryBean;
```

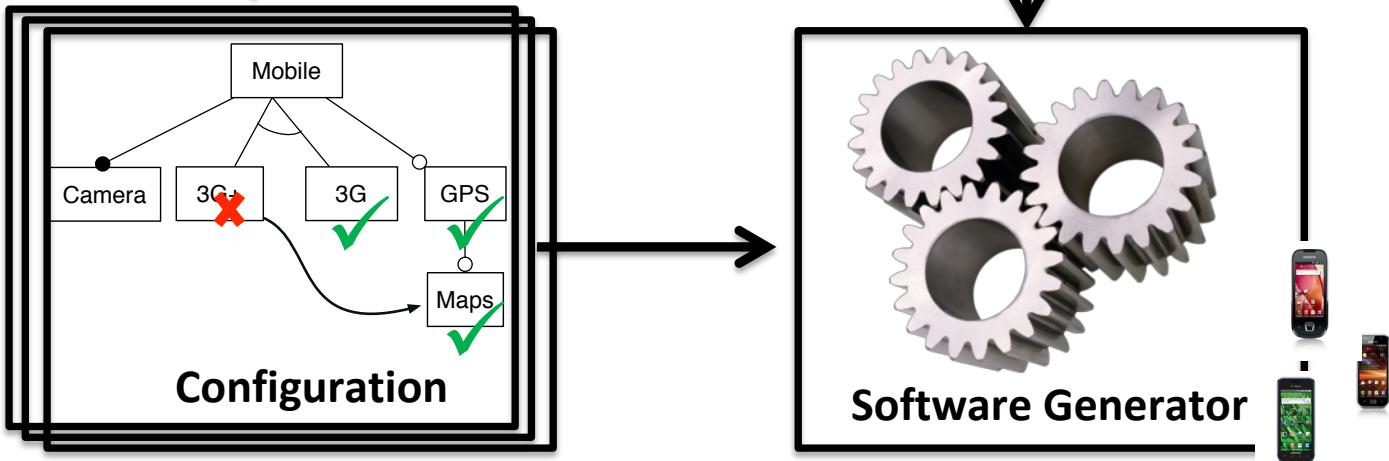
## Base Artefacts

## Software Generator (derivation engine)

# Domain Engineering



# Application Engineering



« the investments required to develop the reusable artifacts during **domain engineering**, are outweighed by the benefits of deriving the individual products during **application engineering** »

Jan Bosch et al. (2004)

« variability »

Is it really new?

# Command Line Options

```
x264 --quiet  
      --no-progress  
      --no-asm  
      --rc-lookahead 60  
      --ref 9  
      -o trailer_480p24.x264  
      trailer_2k_480p24.y4m
```

# Parameter -i in grep

```
1 int match_icase;
2
3 int main (int argc, char **argv)
4 {
5     [...]
6     while ((opt = get_nondigit_option (argc, argv, &default_color))
7         switch (opt)
8         {
9             [...]
10            case 'i':
11                match_icase = 1;
12                break;
13            }
14        }
15
16
17 static const char *
18 print_line_middle (const char *beg, const char *lim,
19                     const char *line_color, const char *match_color)
20 {
21     [...]
22     if (match_icase)
23     {
24         ibeg = buf = (char *) xmalloc(i);
25         while (--i >= 0)
26             buf[i] = tolower(beg[i]);
27     }
}
```

# Global configuration

```
class Config {  
    public static boolean isLogging = false;  
    public static boolean isWindows = false;  
    public static boolean isLinux = true;  
}  
class Main {  
    public void foo() {  
        if (isLogging)  
            log(„running foo()“);  
        if (isWindows)  
            callWindowsMethod();  
        else if (isLinux)  
            callLinuxMethod();  
        else  
            throw RuntimeException();  
    }  
}
```

# Configuration

## httpd.conf -- win32 Apache Building a Web Server, for Windows

```
Listen 80
ServerRoot "/www/Apache2"
DocumentRoot "/www/webroot"
```

```
ServerName localhost:80
ServerAdmin admin@localhost
```

```
ServerSignature On
ServerTokens Full
```

```
DefaultType text/plain
AddDefaultCharset ISO-8859-1
```

```
UseCanonicalName Off
```

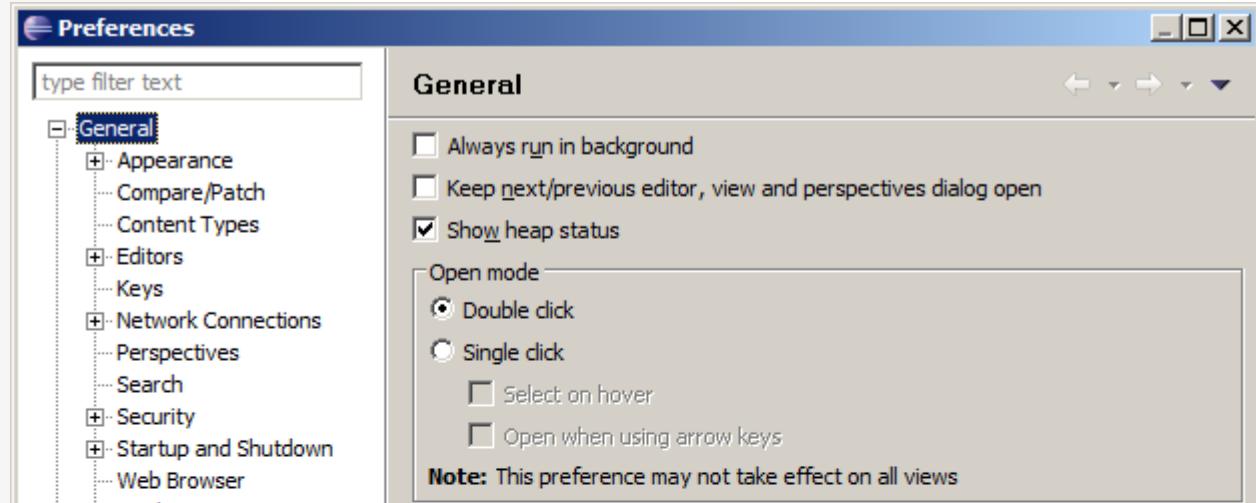
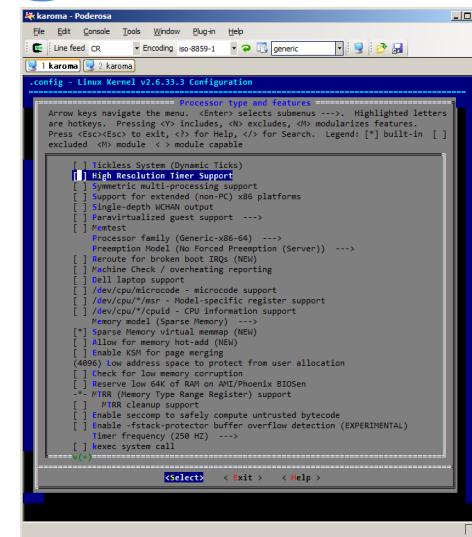
```
HostnameLookups Off
```

```
ErrorLog logs/error.log
LogLevel error
```

```
PidFile logs/httpd.pid
```

```
Timeout 300
```

```
KeepAlive On
MaxKeepAliveRequests 100
```



# Conditional compilation

## #ifdef (Berkeley DB)

```
static int __rep_queue_filedone(dbenv, rep, rfp)
    DB_ENV *dbenv;
    REP *rep;
    __rep_fileinfo_args *rfp; {
#ifndef HAVE_QUEUE
    COMPQUIET(rep, NULL);
    COMPQUIET(rfp, NULL);
    return (__db_no_queue_am(dbenv));
#else
    db_pgno_t first, last;
    u_int32_t flags;
    int empty, ret, t_ret;
#endif
#ifdef DIAGNOSTIC
    DB_MSGBUF mb;
#endif
    // over 100 lines of additional code
}
#endif
```

# Intentional Code Cloning

~ Copy & Paste

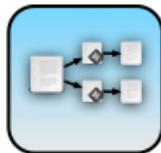
# Code Cloning (example, Linux driver)

cyberstorm.c

```
....  
static void dma_dump_state(struct NCR_ESP *esp)  
{  
    ESPLOG("esp%d: dma -- cond_reg<%02x>\n",  
           esp->esp_id, ((struct cyber_dma_registers *)  
                           (esp->dregs))->cond_reg);  
    ESPLOG("intreq:<%04x>, intena:<%04x>\n",  
           custom.intreq, custom.intenar));  
}  
  
static void dma_init_read(struct NCR_ESP *esp, __u32 addr, int  
length)  
{  
    struct cyber_dma_registers *dregs =  
        (struct cyber_dma_registers *) esp->dregs;  
  
    cache_clear(addr, length);  
  
    addr &= ~(1);  
    dregs->dma_addr0 = (addr >> 24) & 0xff;  
    dregs->dma_addr1 = (addr >> 16) & 0xff;  
    dregs->dma_addr2 = (addr >> 8) & 0xff;  
    dregs->dma_addr3 = (addr ) & 0xff;  
    ctrl_data &= ~(CYBER_DMA_WRITE);  
}.....
```

cyberstormll.c

```
....  
static void dma_dump_state(struct NCR_ESP *esp)  
{  
    ESPLOG("esp%d: dma -- cond_reg<%02x>\n",  
           esp->esp_id, ((struct cyberll_dma_registers *)  
                           (esp->dregs))->cond_reg));  
    ESPLOG("intreq:<%04x>, intena:<%04x>\n",  
           custom.intreq, custom.intenar));  
}  
  
static void dma_init_read(struct NCR_ESP *esp, __u32 addr, int  
length)  
{  
    struct cyberll_dma_registers *dregs =  
        (struct cyberll_dma_registers *) esp->dregs;  
  
    cache_clear(addr, length);  
  
    addr &= ~(1);  
    dregs->dma_addr0 = (addr >> 24) & 0xff;  
    dregs->dma_addr1 = (addr >> 16) & 0xff;  
    dregs->dma_addr2 = (addr >> 8) & 0xff;  
    dregs->dma_addr3 = (addr ) & 0xff;  
}  
.....
```

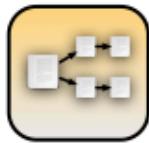


# Replicate & Specialize

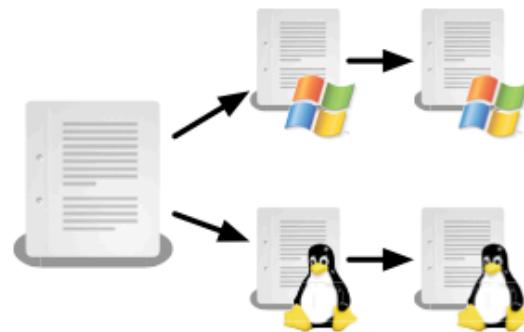


## Clone to reuse and adapt existing solutions

- + Less effort needed
- Long-term cost outweighs short-term benefit
- ~ Cost of refactoring rises over time

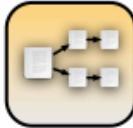


# Platform Variations



**Clone existing code and fix  
low level platform interaction**

- + Avoid complexity of virtualization layer
- Hard to propagate bug fixes
- ~ Ensure consistent behavior of all clones



# Hardware Variations



## Clone existing driver

- + No risk of changing existing driver
- Code growth
- ~ Dead code can creep into system

# Inheritance (OOP)

Base Class encapsulate commonalities

Derive classes specialize peculiarities

# Generic Programming

## C++ template

```
template <typename T>
T max(T x, T y)
{
    return x < y ? y : x;
}
```

## Generics in Java

```
public interface List<E> {
    void add(E x);
    Iterator<E> iterator();
}
public interface Iterator<E> {
    E next();
    boolean hasNext();
}
```

# Design Patterns

Template Method

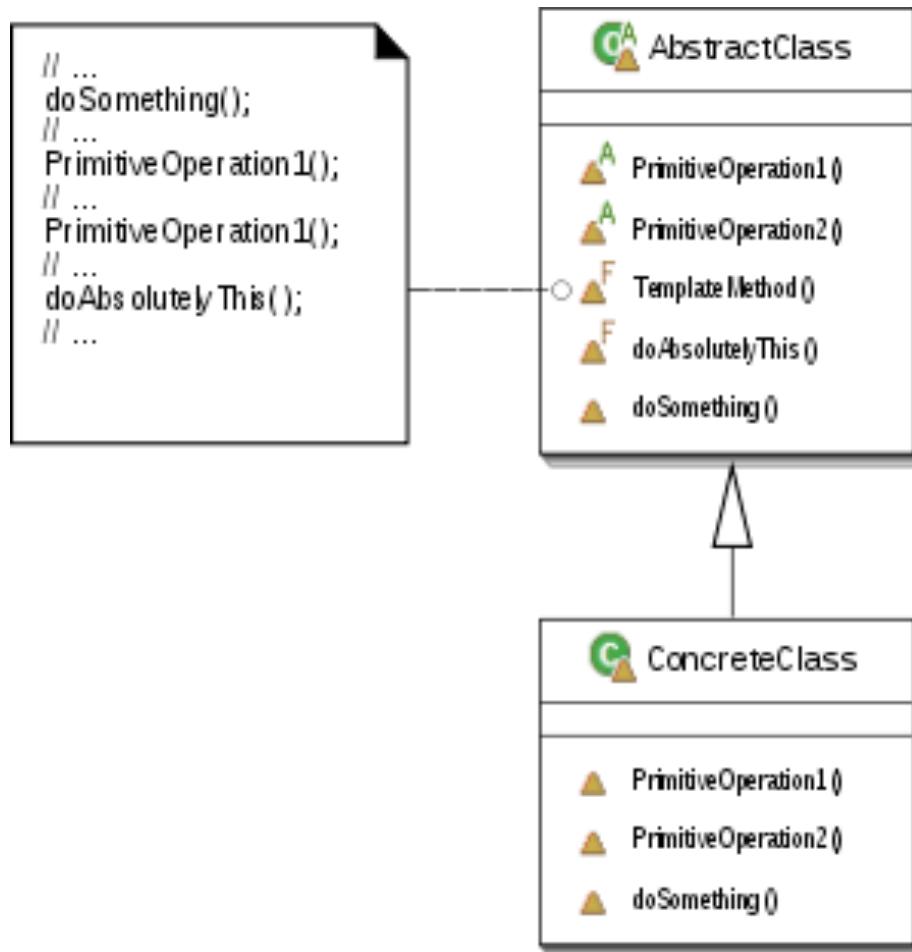
Factory

Strategy

Decorator

....

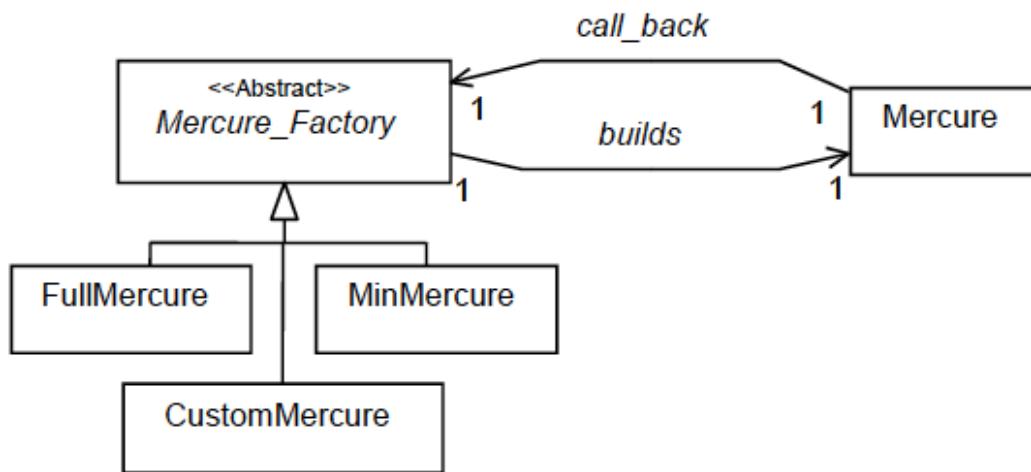
# Template Method



# The decision model

## ■ The Abstract Factory Design Pattern – [Gamma et al 95]

Mercure_Factory
new_gui() : GUI
new_language() : Language
new_network_manager() : Manager
new_netdriver() : Net Driver
new_engine() : Engine



CustomMercure
<<GUI1>> <<GUI2>> new_gui() : GUI
<<<Language2-1>> new_language() : Language
<<Manager1>> new_network_manager() : Manager
<<NetDriver1>> <<NetDriver2>> new_netdriver() : Net Driver
<<Engine1>> new_engine() : Engine

# API Framework

# Plugin-based systems

# (Active) Annotations

can have parameters

# Metamodeling and Domain-Specific Languages

# httpd.conf -- win32 Apache

## Building a Web Server, for Windows

```
Listen 80
ServerRoot "/www/Apache2"
DocumentRoot "/www/webroot"

ServerName localhost:80
ServerAdmin admin@localhost

ServerSignature On
ServerTokens Full

DefaultType text/plain
AddDefaultCharset ISO-8859-1

UseCanonicalName Off

HostnameLookups Off

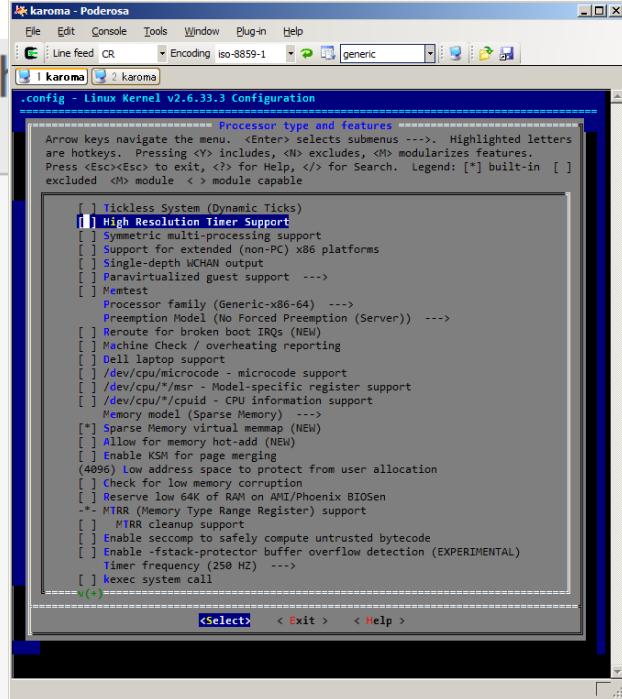
ErrorLog logs/error.log
LogLevel error

PidFile logs/httpd.pid

Timeout 300

KeepAlive On
MaxKeepAliveRequests 100
KeepAliveTimeout 15

<IfModule mpm_winnt.c>
    ThreadsPerChild 250
    MaxRequestsPerChild 0
</IfModule>
```



A screenshot of the Renault Vans website. The top navigation bar includes links for CARS, VANS, ELECTRIC VEHICLES, RENAULT BUSINESS, USED CARS, OWNER SERVICES, ABOUT RENAULT, and RENAULT SHOP. Below the navigation, a breadcrumb trail shows Renault UK > Renault Vans > New Kangoo Van Range > Kangoo Van > Build your own Kangoo Van > Selected Options. The main content area is titled 'NEW KANGOO VAN RANGE' and contains three tabs: '01 Preferences', '02 Version', and '03 Equipment & options'. Under 'OPTIONS', there are sections for 'COMFORT' (Central storage console & armrest between seats, £50.00), 'DRIVING' (Electric door mirrors, £0.00), and 'SAFETY & SECURITY' (ESC (Electronic Stability Control) with traction and understeer control, £200.00). To the right, a silver Renault Kangoo van is shown. The URL in the browser's address bar is 'http://www.renault.com/vans/build-your-own/kangoo-van-range/selected-options'.

A screenshot of the Eclipse IDE. The central part shows a Java code editor with three files: Notepad.java, Actions.java, and Main.java. The code includes various Java statements like setText, apply, and isSelected. A note in the code editor says: 'Note: This preference is not yet supported by the Java Editor.' To the right of the code editor is the 'ASTView' panel, which displays the Abstract Syntax Tree (AST) for the selected code. The tree structure shows nodes for statements, expressions, and other language constructs. The URL in the browser's address bar is 'http://www.eclipse.org/eclipse-platform/Downloads/eclipse-jdt-eclipselink-rc1-win32-x86\_64.zip'.

A photograph of an old, green-painted pickup truck that has been left to decay in a field. The truck is heavily rusted, particularly on the body and the front fenders. The driver's side door is open, revealing the interior frame and some remaining mechanical components. The truck is positioned in front of a dense thicket of green bushes and tall grass. In the bottom left corner, there are some wooden planks and metal debris, suggesting a construction or demolition site nearby.

Unused flexibility



Illegal variant

# Feature Models

A screenshot of the karmo configuration tool. The window title is ".config - Linux Kernel v2.6.33.5 Configuration". It displays a list of kernel features with checkboxes. Some features have descriptive text next to them. At the bottom, there are buttons for 'select', '< Exit >', and '< Help >'.

Variability Model

A screenshot of an IDE showing Java source code. The code is annotated with various colors (green, yellow, orange, blue) and highlights. On the right side, the 'ASTView' plugin interface is visible, showing a tree structure of the annotated code. The tree includes nodes for 'STATEMENTS(5)', 'EXPRESSION', 'METHOD\_INVOCATION', 'THEN\_STATEMENT', 'ELSE\_STATEMENT', and several 'IfStatement' nodes with numerical IDs.

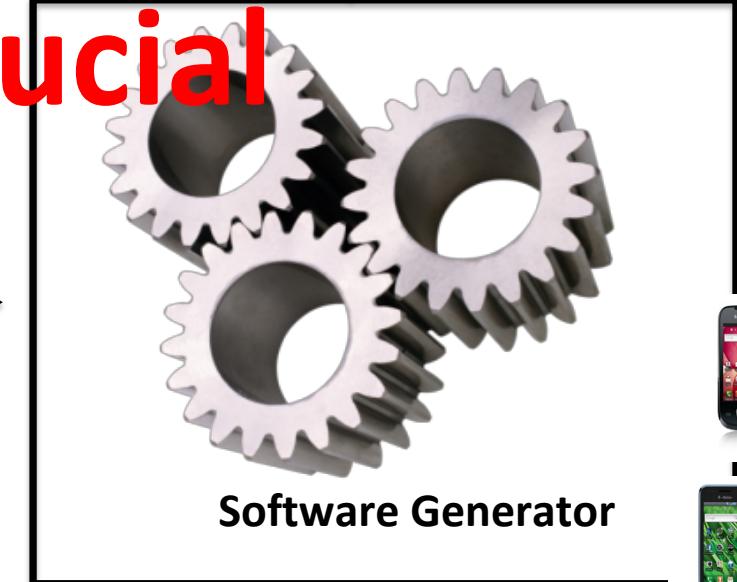
Modeling variability in main artifacts (e.g., source code)



Configuration



is crucial



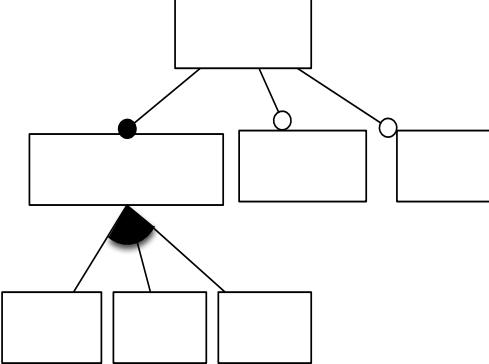
# Unused flexibility





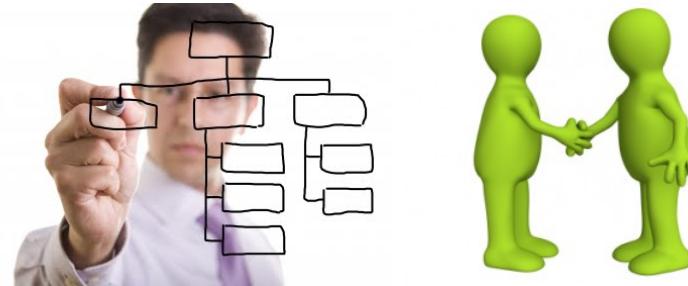
Illegal variant

# Feature Model



not, and, or, implies

## Communicative



## Analytic



## Generative





## R8 Spyder

5.2 FSI quattro R tronic

### Prix total

**171.216,00 EUR**

Prix de base

**170.490,00 EUR**

Equipements optionnels

**726,00 EUR**

- ▶ Informations détaillées
- ▶ Entrez l'Audi Code
- ▶ Générer un PDF
- ▶ Nouvelle configuration



[+] Plein écran / Dimensions

▶ Fermer la capote

Habitacle

Tableau de bord

### Packs

Aucun pack n'est proposé pour ce modèle.

### Couleurs

Blanc Ibis

Noir

Prix: 0,00 EUR



Couleurs métallisées à partir de 0,00 EUR



Couleurs à effet perlé à partir de 0,00 EUR

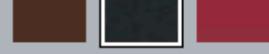


Couleurs personnalisées Audi exclusive



### Couleur capote

Noir



### Jantes

4 Jantes alu 5 BRANCHES ROTOR finition titane 8,5 x 19 à l'avant, 11 x 19 à l'arrière. Pneus 235/35 R19 à l'avant et 305 /30 R19 à l'arrière

Prix: 726,00 EUR

**19" à partir de 0,00 EUR**





## R8 Spyder 5.2 FSI quattro R tronic

Prix total

**185.899,35 EUR**

Prix de base

**170.490,00 EUR**

Equipements optionnels

**15.409,35 EUR**

▶ Informations détaillées

▶ Entrez l'Audi Code

▶ Générer un PDF

▶ Nouvelle configuration

[+] Plein écran / Dimensions    [+] Vue extérieure    [+] Tableau de bord

- ▶ Packs d'équipements
- ▶ Extérieur
- ▶ Jantes & pneumatiques
- ▶ Intérieur
- ▶ Volants
- ▶ Sièges
- Sécurité & technique**
- ▶ Infotainment

- ▶ Châssis
- ▶ Freins
- Systèmes d'assistance**
- ▶ Autres

excludes



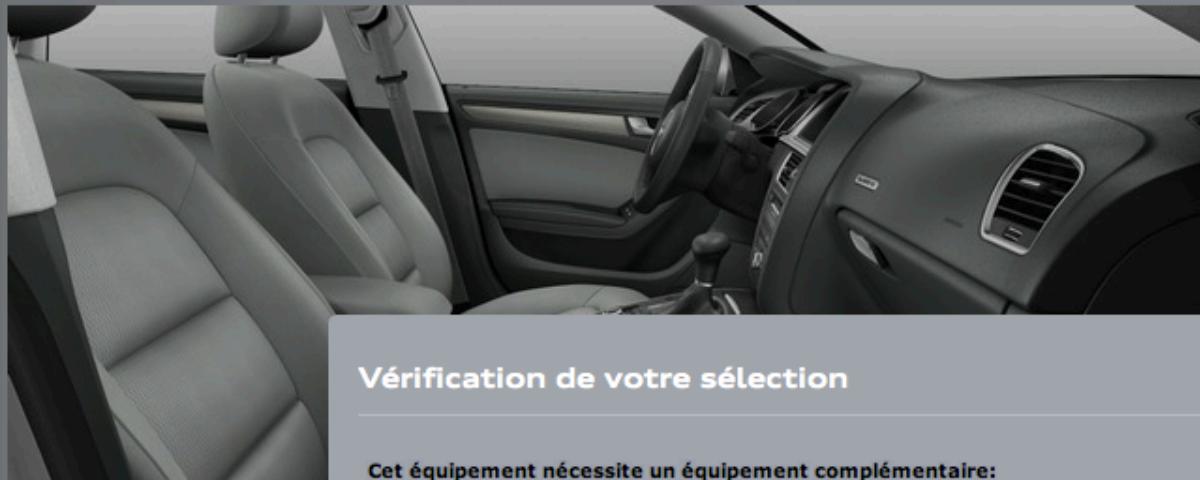
<input checked="" type="checkbox"/> Régulateur de vitesse	320,65 EUR
<input type="checkbox"/> Système d'aide au stationnement APS avant / arrière	931,70 EUR
<input type="checkbox"/> Système d'aide au stationnement APS avant / arrière avec affichage dans l'écran MMI	1.373,35 EUR
<input checked="" type="checkbox"/> Système d'aide au stationnement Advanced : APS avant et arrière et caméra arrière	1.790,80 EUR
<input checked="" type="radio"/> Audi hill assist : assistance au démarrage en côte	Série
<input type="checkbox"/> Réinitialiser la sélection	

**Attention:**

Le prix peut varier en fonction du choix de moteur et des équipements.

**Un aperç des équipements:**

Mode expert



## A5 Sportback 3.0 TDI quattro S tronic

### Prix total

**54.460,15 EUR**

Prix de base

**50.570,00 EUR**

Equipements optionnels

**3.890,15 EUR**

▶ Informations détaillées

▶ Entrez l'Audi Code

▶ Nouvelle configuration

### Vérification de votre sélection

Cet équipement nécessite un équipement complémentaire:

GPS Plus avec disque dur



2.934,25 EUR

Voici les équipements complémentaires possibles:

Ordinateur de bord en couleur avec programme efficiency



181,50 EUR

Remarque: uniquement sur les modèles avec système Start-Stop et uniquement disponible en combinaison avec l'autoradio Concert, l'autoradio Symphony ou un système de navigation

Pack Intenso Plus



3.100,00 EUR

Sans appareil de navigation

Série

[+] Plein écran / Dimensions

- ▶ Packs d'équipements
- ▶ Extérieur
- ▶ Jantes & pneumatiques
- ▶ Intérieur
- ▶ Volants
- ▶ Sièges
- ▶ Sécurité & technique

**Infotainment**

#### Attention:

Le prix peut varier en fonction du choix de moteur et des équipements.

#### Un aperç des équipements:

Mode expert

Réinitialiser la sélection

**1 Modèle**

**2 Moteur**

**3 Extérieur**

**4 Intérieur**

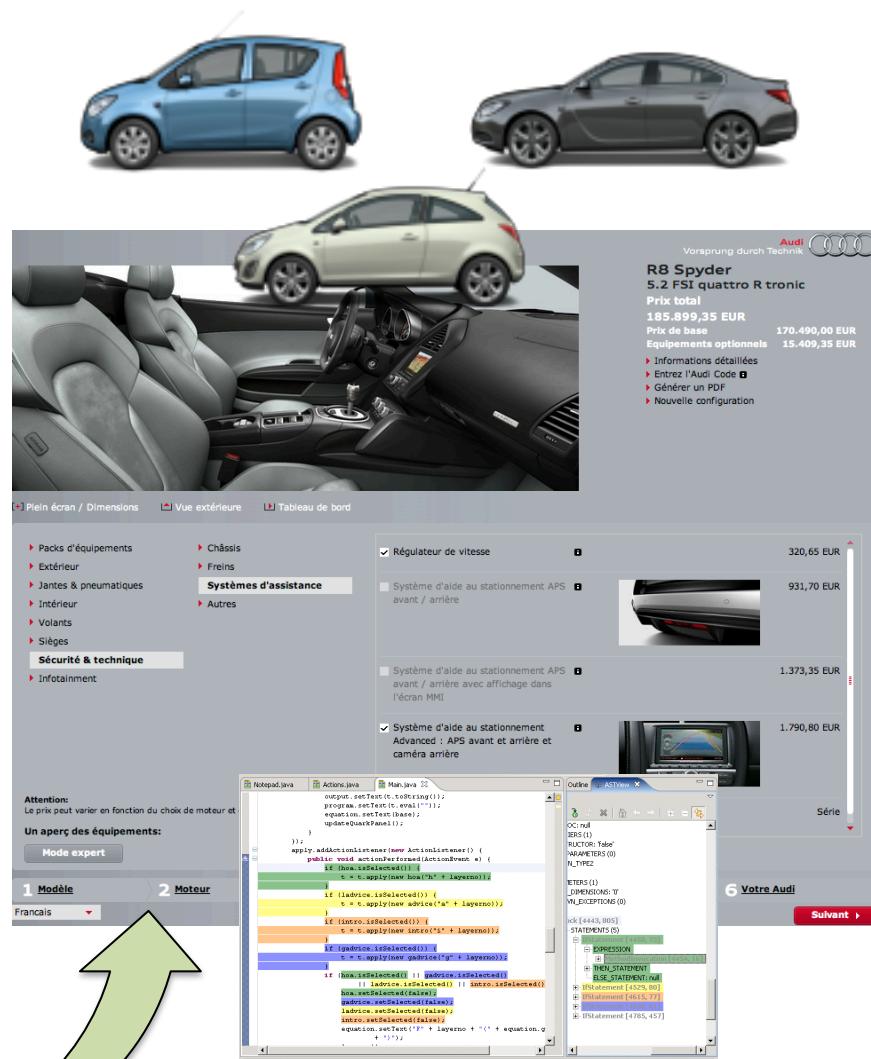
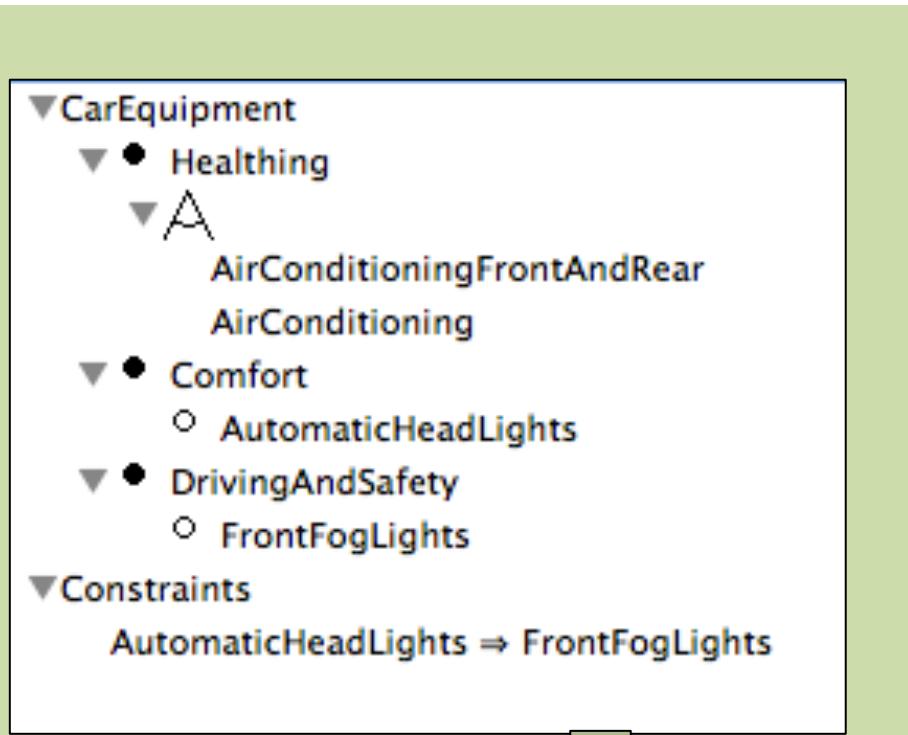
**5 Option**

**6 Votre Audi**

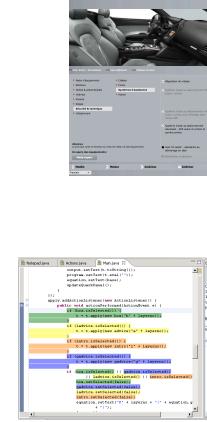
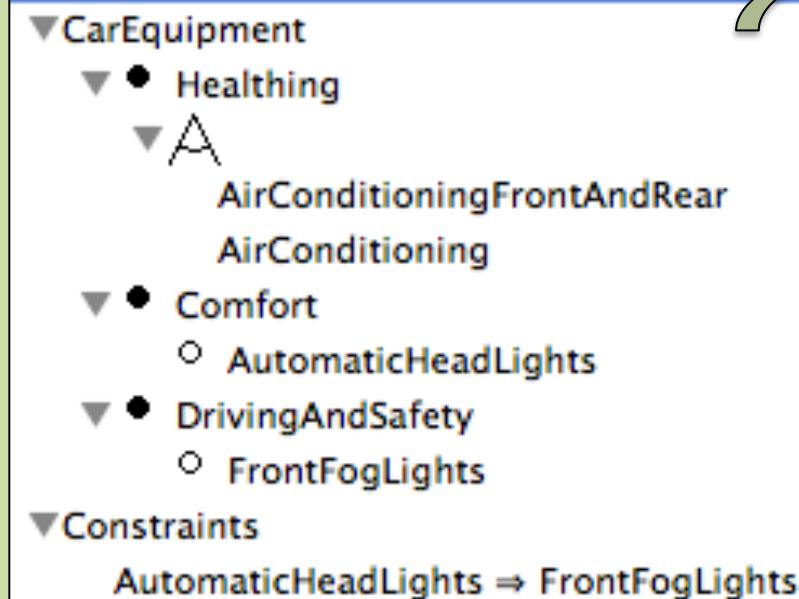
Français ▾

Suivant ▶

# Feature Models



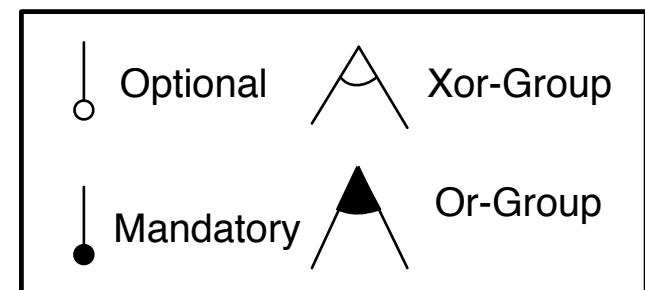
# Feature Models (Background)

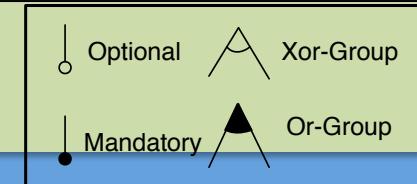
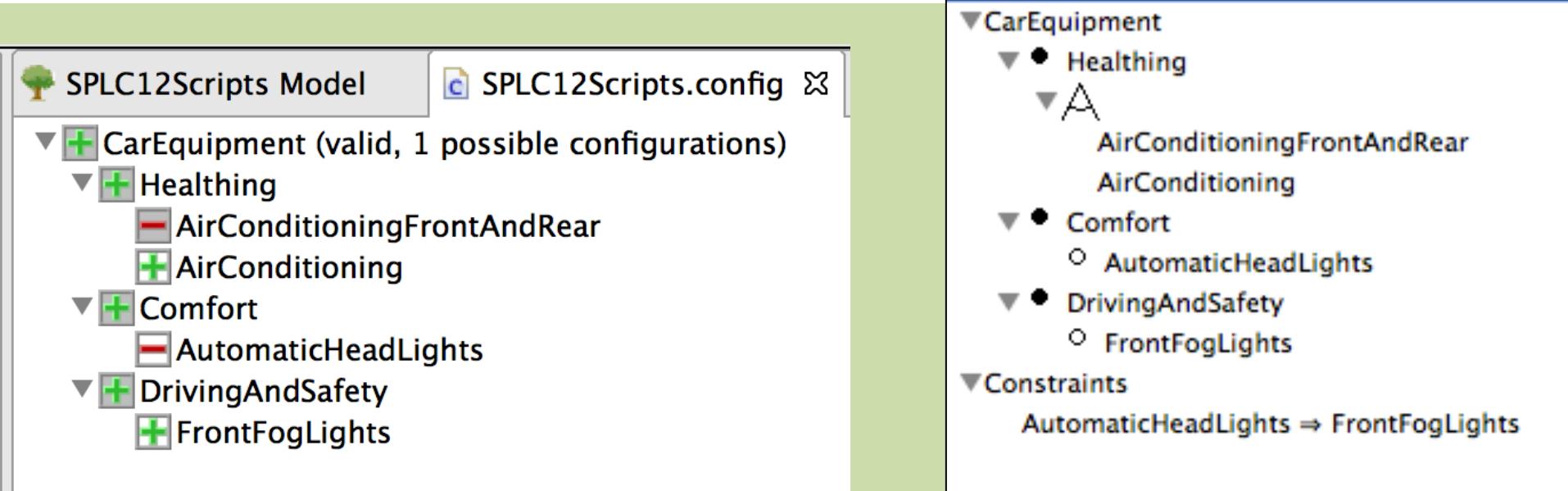


**Hierarchy:** rooted tree

**Variability:**

- mandatory,
- optional,
- Groups: exclusive or inclusive features
- Cross-tree constraints





## Hierarchy + Variability

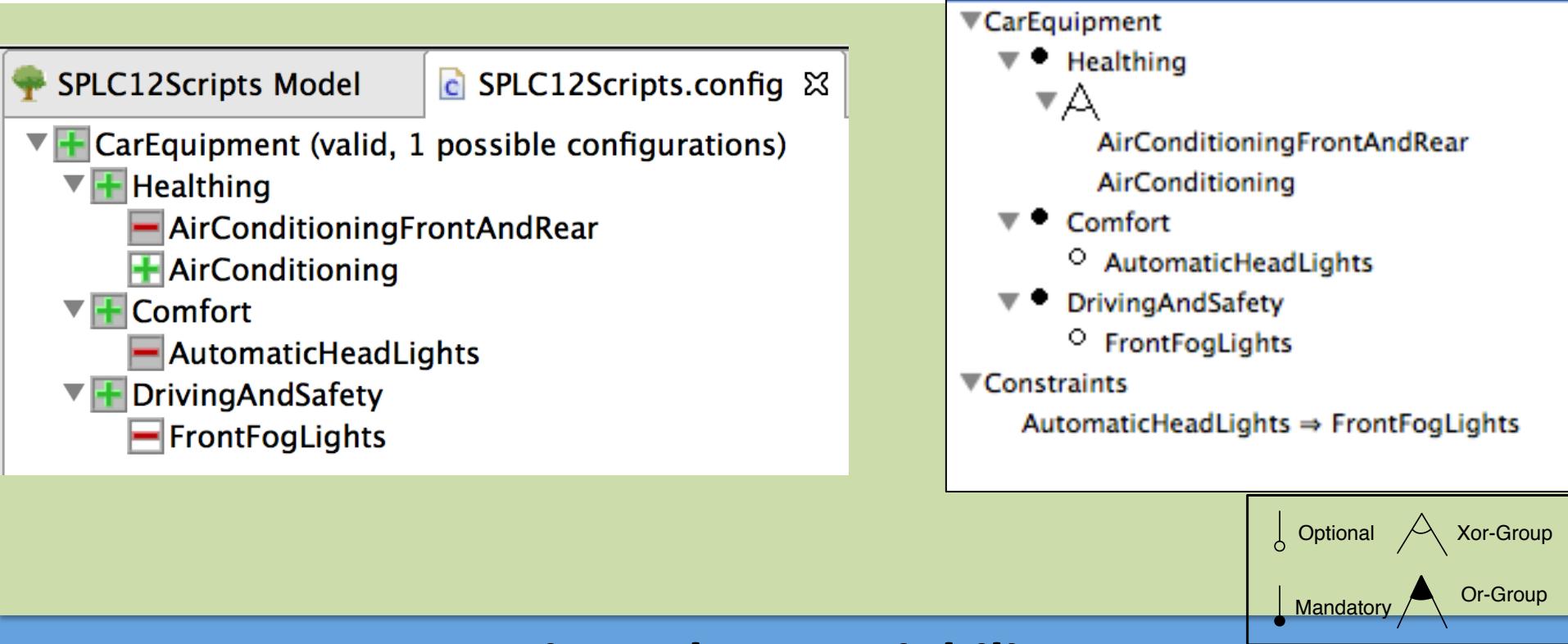
=

## set of valid configurations

**configuration = set of features selected**

{CarEquipment, Comfort, DrivingAndSafety, Healthing, AirConditioning, FrontFogLights}





## Hierarchy + Variability

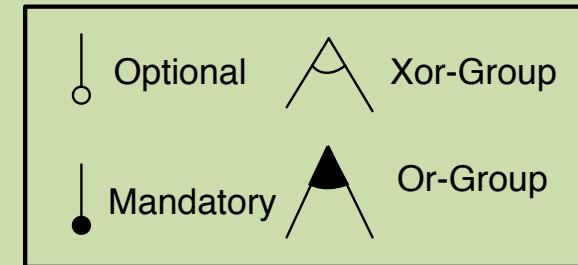
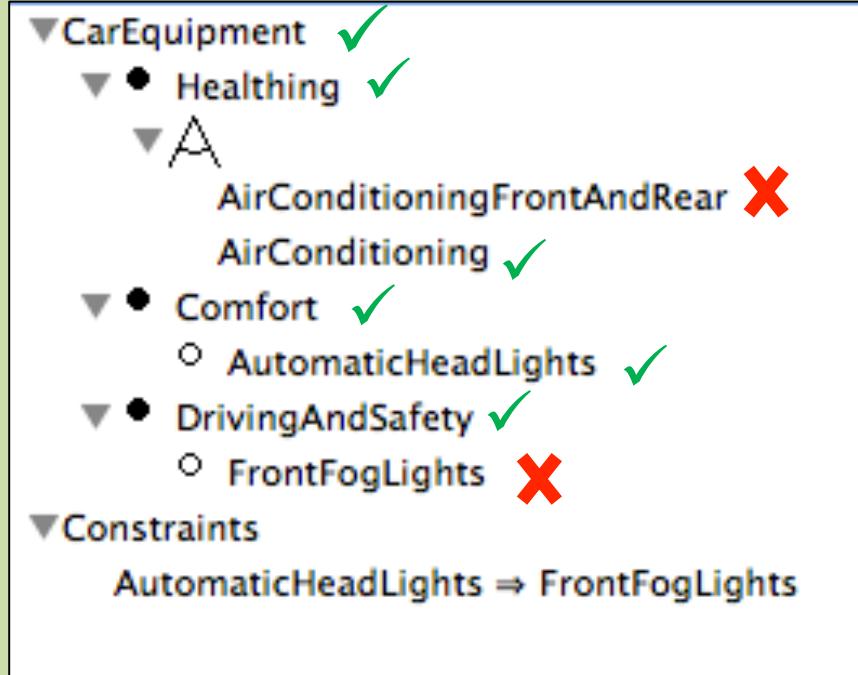
=

## set of valid configurations

**configuration = set of features selected**

{CarEquipment, Comfort, DrivingAndSafety, Healthing, AirConditioning}





## Hierarchy + Variability

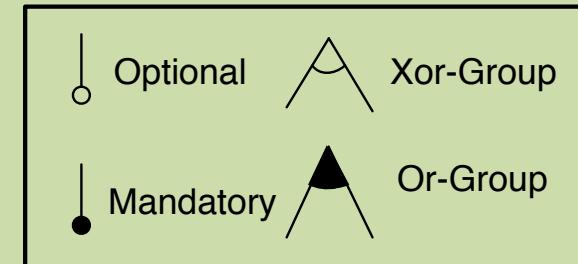
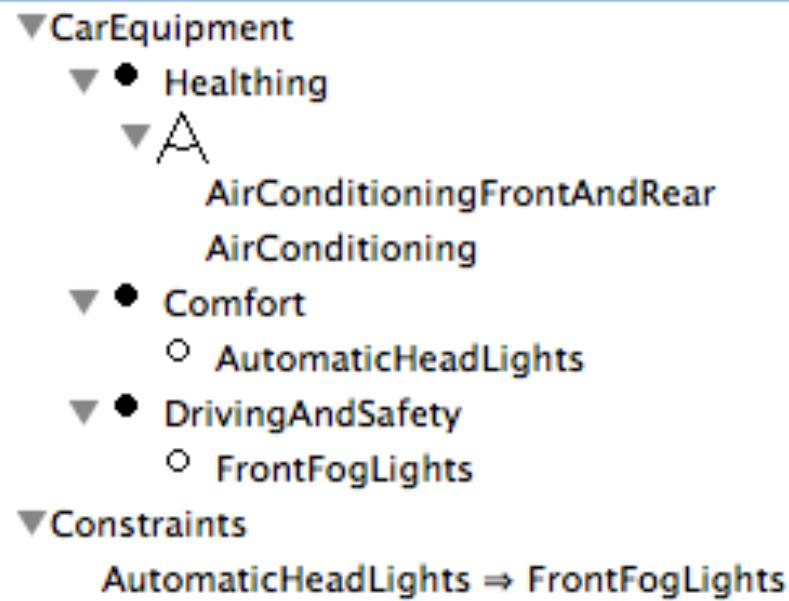
=

## set of valid configurations

configuration = set of features selected

{CarEquipment, Comfort, DrivingAndSafety, Healthing, AirConditioning, AutomaticHeadLights}





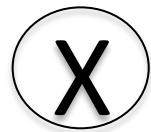
## Hierarchy + Variability

=

## set of valid configurations

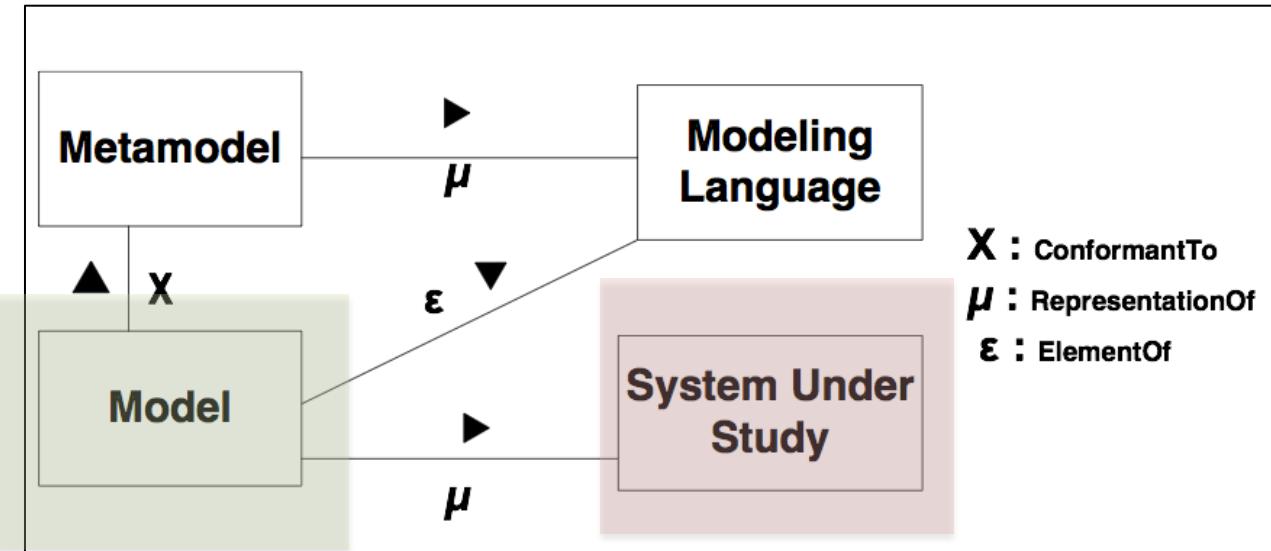


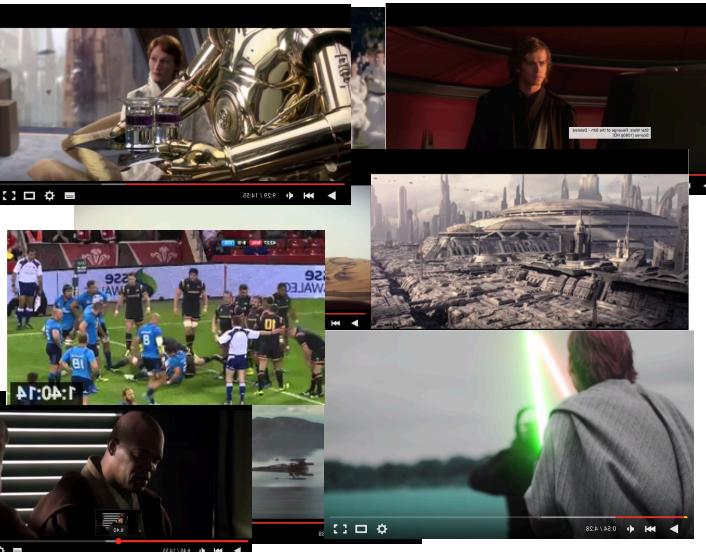
{CarEquipment, Comfort,  
DrivingAndSafety,  
Healthing}



- {AirConditioning, FrontFogLights}
- {AutomaticHeadLights, AirConditioning, FrontFogLights}
- {AutomaticHeadLights, FrontFogLights, AirConditioningFrontAndRear}
- {AirConditioningFrontAndRear}
- {AirConditioning}
- {AirConditioningFrontAndRear, FrontFogLights}

# Feature Models

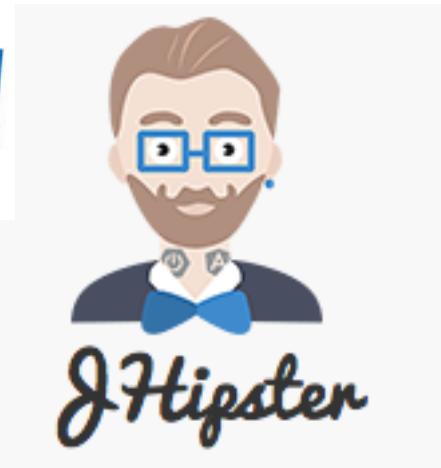
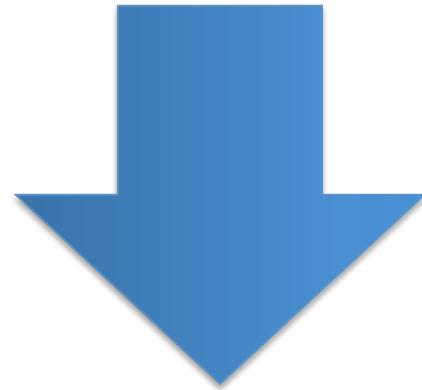




```
foo1.videogen ✘

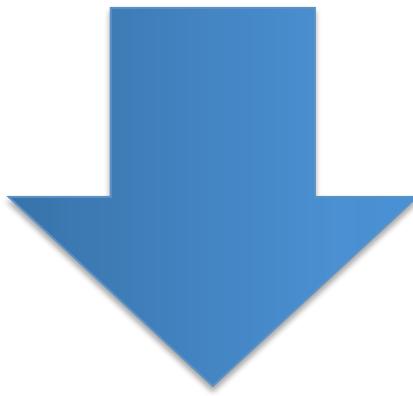
mandatory videoseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"
optional videoseq v2 "v2Folder/v2.mp4"
alternatives v3 {
    videoseq v31 "v3/seq1.mp4"
    videoseq v32 "v3/seq1.mp4"
    videoseq v33 "v3/seq1.mp4"
}

alternatives v4 {
    videoseq v41 "v4/seq1.mp4"
    videoseq v42 "v4/seq1.mp4"
}
mandatory videoseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"
```



 FFmpeg

```
VideoGen {  
    mandatory videoseq v1 "V1/v1.mp4"  
    optional videoseq v2 "v2folder/v2.mp4"  
    alternatives v3 {  
        videoseq v31 "v31.mp4"  
        videoseq v32 "v32.mp4"  
    }  
}
```



model-to-text

```
fmVideoGen = FM (VideoGen: v1  
[v2] v3; v3: (v31|v32); )
```

FAMILIAR

# Product line and variability everywhere

- Your video generator is a product line
  - Generalization of Bref generator
  - It is even a configurable generator
  - There is an hidden feature model in every VideoGen specification
- Xtext is a configurable generator (see MWE2)
- JHipster is a product line
- ffmpeg is a product line

# JHipster

## Case Study

# Other references

- Krzysztof Czarnecki and Ulrich Eisenecker "Generative Programming: Methods, Tools, and Applications"
- S. Apel, D. Batory, C. Kästner, and G. Saake. Feature-Oriented Software Product Lines: Concepts and Implementation. Berlin/Heidelberg: Springer-Verlag, 2013.
- Cory Kapser, Michael W. Godfrey: "Cloning considered harmful" considered harmful: patterns of cloning in software. Empirical Software Engineering 13(6): 645-692 (2008)
- C. Kästner. Virtual Separation of Concerns: Toward Preprocessors 2.0. PhD thesis, 2010
- Klaus Pohl, Günter Böckle, Frank van der Linden: Software Product Line Engineering - Foundations, Principles, and Techniques. Springer 2005

# Other references

- Krzysztof Czarnecki, Krzysztof Pietroszek: Verifying feature-based model templates against well-formedness OCL constraints. GPCE 2006: 211-220
- José A. Galindo, Mauricio Alferez, Mathieu Acher, Benoit Baudry, and David Benavides. A Variability-based Testing Approach for Synthesizing Video Sequences (2014). In ISSTA'14
- Sarkar, A., J. Guo, N. Siegmund, S. Apel, and K. Czarnecki, "Cost-Efficient Sampling for Performance Prediction of Configurable Systems" In ASE'2015
- Mathieu Acher, Guillaume Bécan, Benoit Combemale, Benoit Baudry, and Jean-Marc Jézéquel. Product lines can jeopardize their trade secrets (2015). In ESEC/FSE'15