

Model-based Software Product Lines Overview and Principles

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Material

<http://mathieuacher.com/teaching/MDE/>

**TP
3**

Another DSL

```
PollStyle<Question> pollStyle = new PollStyle<Question>() {
    Question q1 {
        "Value the user experience"
        options {
            A : "Bad"
            B : "Fair"
            C : "Good"
        }
    }
    Question q2 {
        "Value the layout"
        options {
            A : "It was not easy to locate elements"
            B : "I didn't realize"
            C : "It was easy to locate elements"
        }
    }
    PollResponse<Question> pollResponse {
        "Value the time response"
        options {
            A : "Bad"
            B : "Fair"
            C : "Good"
        }
    }
}
```

Questionnaire.xtext

**TP
2**

Model-to-Model

**TP
4**

**Pivot
MM**

**TP
3**

**UI
model**



Model-to-Text

Generator

**TP
5**



Plan

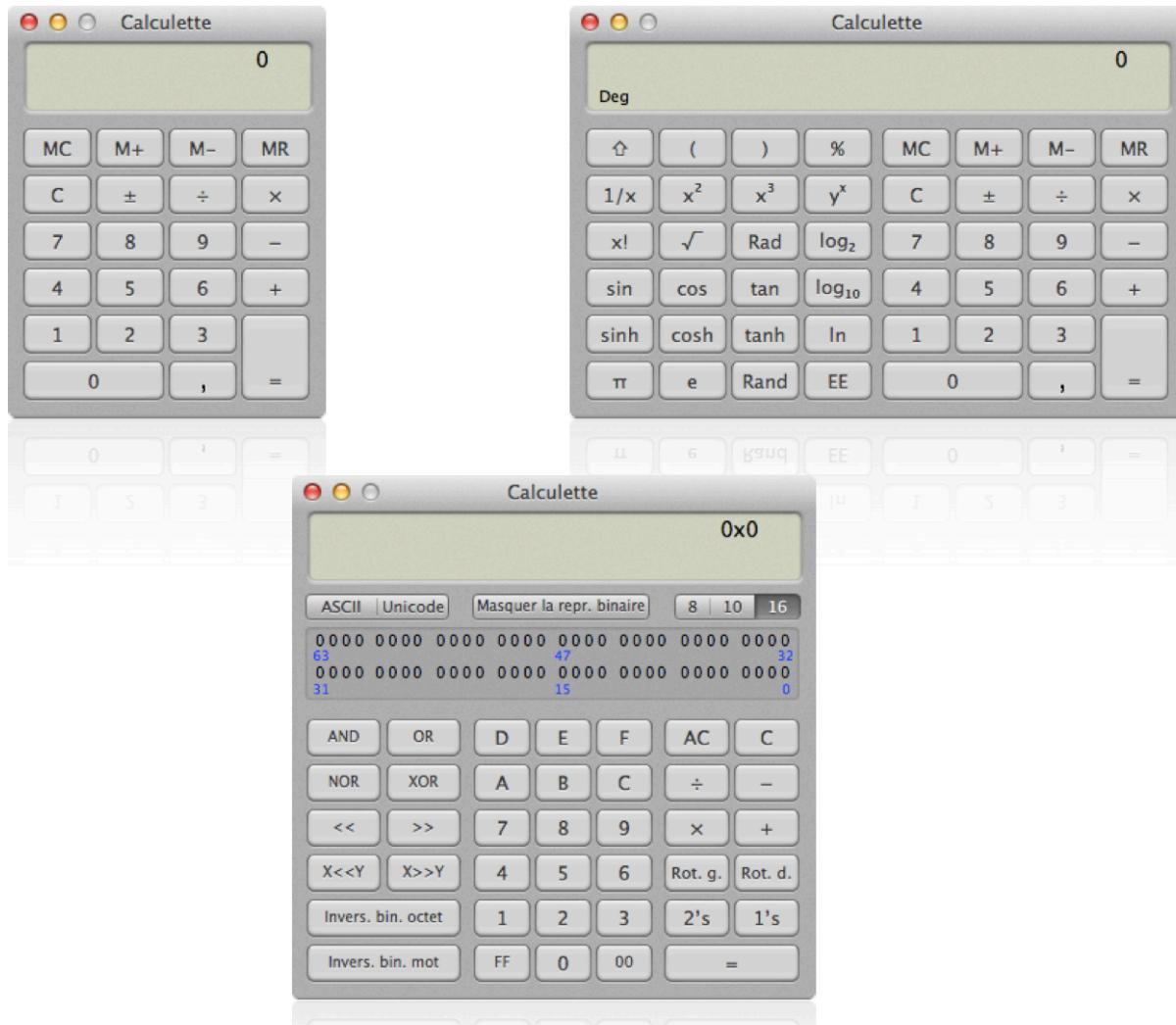
- Challenges and Overview
 - Developing billions of software product is hard but now a common practice
- Implementing Variability
 - Revisit of existing techniques and curriculum
- Specificity of Product Line Engineering
 - Process, methods
- Feature Models
 - Defacto standard for modeling product lines and variability

Contract

- The idea of software product lines and variability
 - You will be able to recognize this class of systems
 - Aware of the complexity
 - Aware of the specific development process
 - Aware of existing techniques
- Feature modeling
 - A widely used formalism for modeling product lines and configurable systems in a broad sense

Software Product Line and Variability Engineering

Challenges and Overview



« A set of programs is considered to constitute a **family**, whenever it is worthwhile to study programs from the set by **first studying the common properties** of the set and then determining the **special properties** of the individual family members »



aka Variability

David L. Parnas — “On the design and development of program families” in Transactions on Software Engineering, SE-2(1):1–9, 1976⁸

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\$219.99*

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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			✓	✓

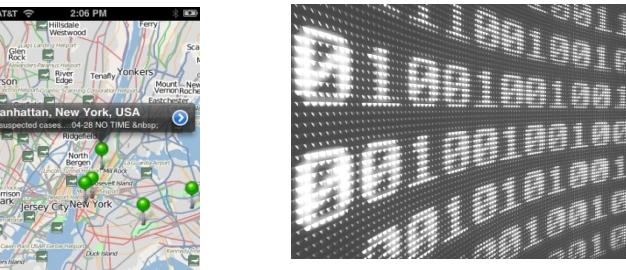
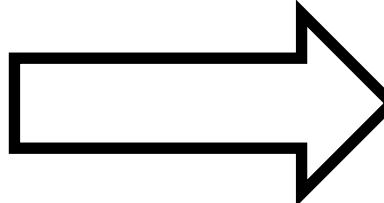
Entertainment

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





Software-intensive systems

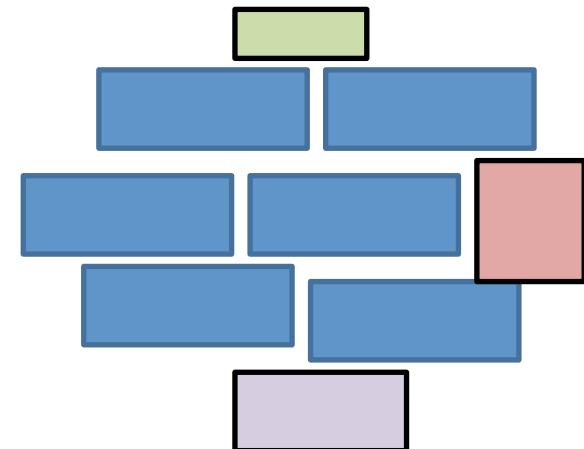


come in many variants

Software Product Line Engineering

Factoring out **commonalities**

for **Reuse** [Krueger et al., 1992] [Jacobson et al., 1997]



Managing **variabilities**

for Software **Mass Customization** [Bass et al., 1998] [Krueger et al., 2001], [Pohl et al., 2005]

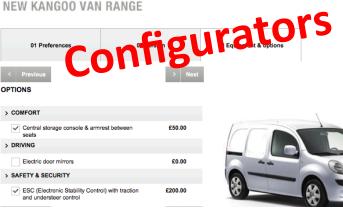


Variability

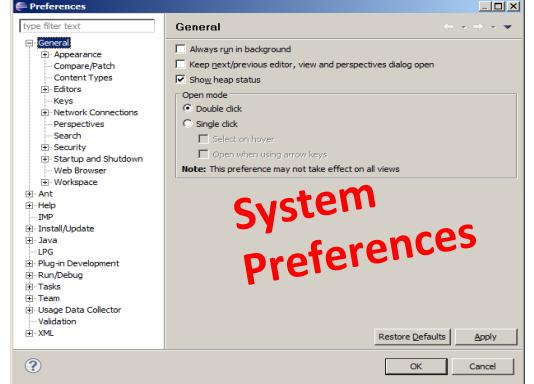
“the ability of a system to be efficiently extended, changed, customized or configured for use in a particular context”

Mikael Svahnberg, Jilles van Gurp, and Jan Bosch (2005)

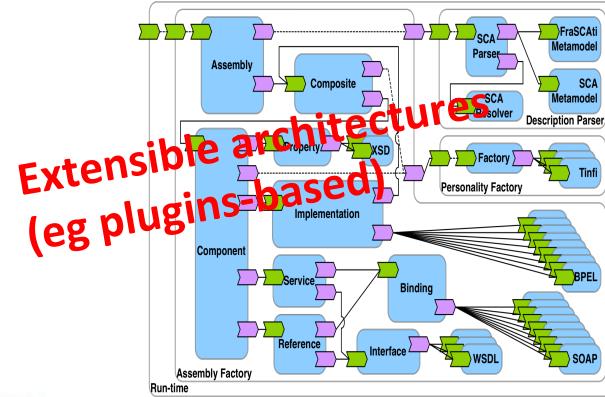




Configurators



System Preferences



Extensible architectures
(eg plugins-based)

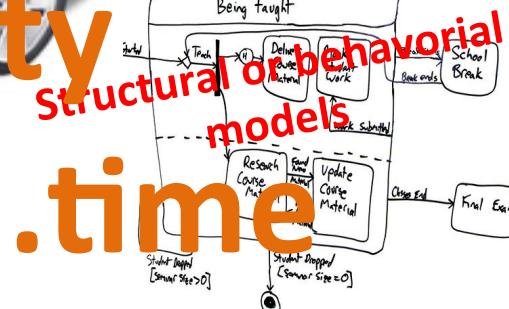


Comparison of*

External Variability

Internal Variability

Variability @ run.time



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

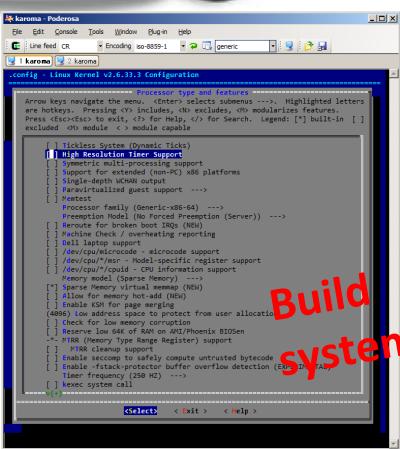
PidFile logs/httpd.pid

Timeout 300

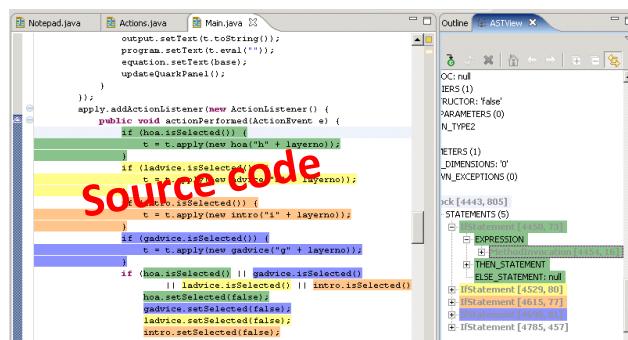
KeepAlive On
MaxKeepAliveRequests 100
KeepAliveTimeout 15

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

Configuration files



Build systems



Source code

Developer Tools
Development
Drivers
DTP/Prepress
Educational
Finance
Font Tools
Games
Graphics
HTML Tools
Internet Utilities
iPhone Applications
iPod Tools
Math/Scientific
Multimedia
Network/Admin
Screensavers
Security
Spotlight Plugins
Utilities
System Utilities
Video
Word Processing
 GLOBAL PAGES >>
NEWS ARCHIVE >>
DAFTOPEDIA REVIEWS >>
MEET THE EDITORS >>

variability

Power Matte 2.1.3 update

 Adobe Acrobat plugin that can extract a subject in an image

[\[read more >\]](#)

Size: 13.20 MB
Platform: Mac OS X 10.5 or later
License: Trial
Rating: Good (3.0/5)
Downloads: 1,504
Updated: June 20th, 08:21 UTC

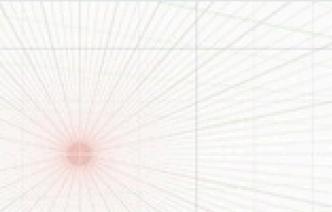


Grids 1.1 update

 Helps you generate perspective grids

[\[read more >\]](#)

Size: 102 KB
Platform: Mac OS X 10.8 or later
License: Commercialware
Rating: NOT RATED
Downloads: 21
Updated: June 20th, 07:56 UTC



Picture Frame 2.2 update

 Quickly generate multi-frame photos using your Mac

[\[read more >\]](#)

Size: 716 KB
Platform: Mac OS X 10.6.6 or later
License: Commercialware
Rating: Excellent (5.0/5)
Downloads: 297
Updated: June 20th, 07:53 UTC

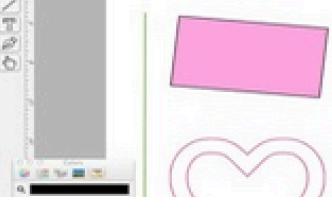


FashionLab Studio 1.1 update

 Makes it easy to design your own T-shirt using a Mac

[\[read more >\]](#)

Size: 3.10 MB
Platform: Mac OS X 10.6.6 or later
License: Commercialware
Rating: NOT RATED
Downloads: 3
Updated: June 20th, 07:49 UTC





RENAULT VANS



CARS | VANS | ELECTRIC VEHICLES | RENAULT BUSINESS | USED CARS | OWNER SERVICES | ABOUT RENAULT | RENAULT SHOP NEW

Renault UK > Renault Vans > New Kangoo Van Range > Kangoo Van > Build your own Kangoo Van > Select Options

NEW KANGOO VAN RANGE

01 Preferences

02 Version

03 Equipment & options

< Previous

Next >

OPTIONS

> COMFORT

- | | |
|---|--------|
| <input checked="" type="checkbox"/> Central storage console & armrest between seats | £50.00 |
|---|--------|

> DRIVING

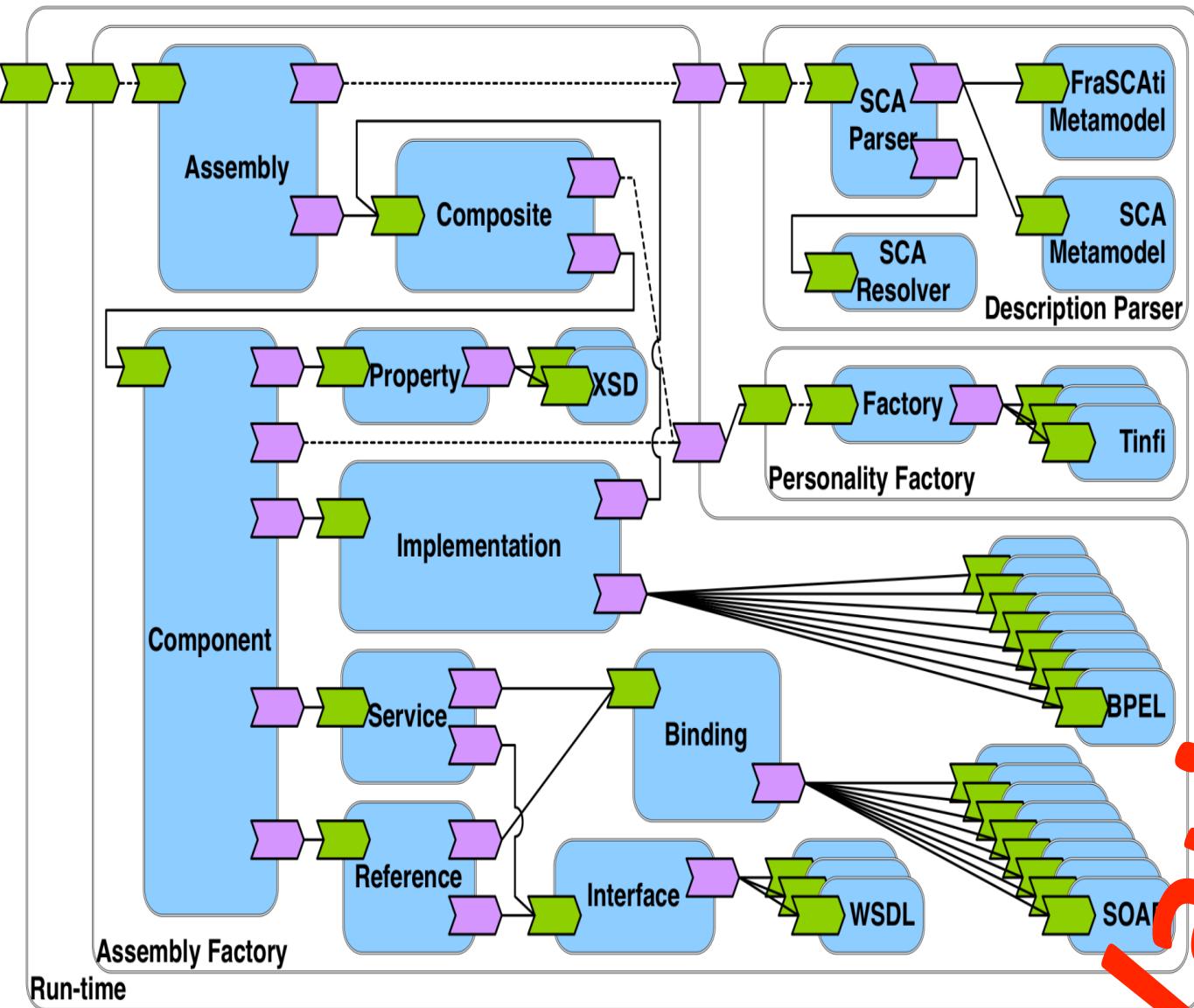
- | | |
|--|-------|
| <input type="checkbox"/> Electric door mirrors | £0.00 |
|--|-------|

> SAFETY & SECURITY

- | | |
|---|---------|
| <input checked="" type="checkbox"/> ESC (Electronic Stability Control) with traction and understeer control | £200.00 |
|---|---------|

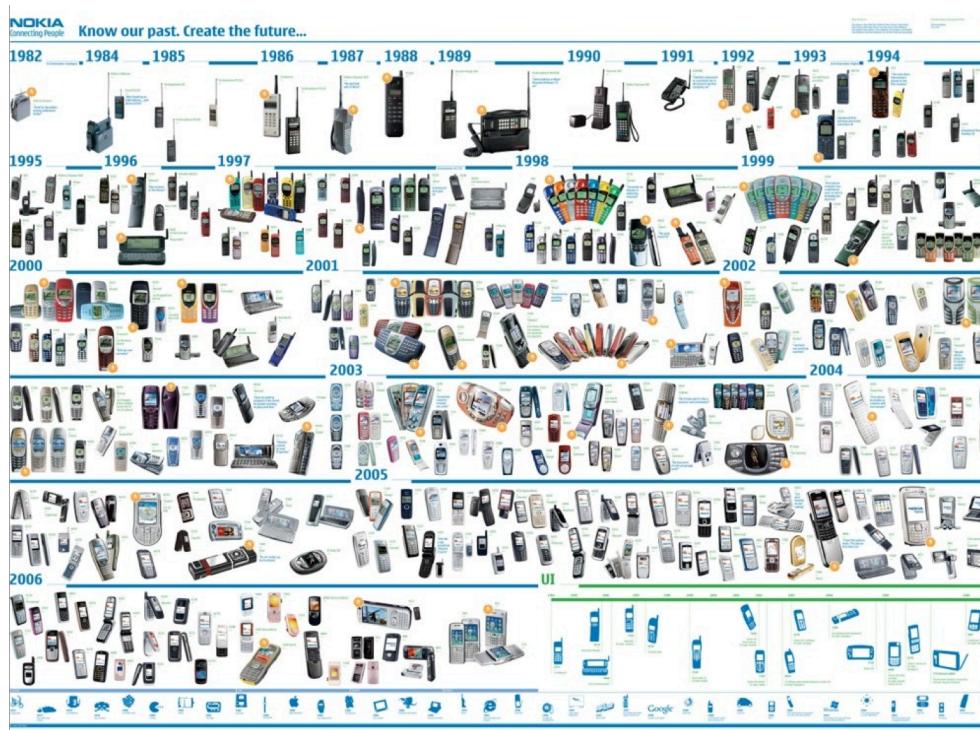


Variability



Variability in time vs in space

- **Variability in Time (releases)**
 - the existence of different **versions** of an artifact that are valid at different times
- **Variability in Space (variants)**
 - the existence of an artifact in different **shapes** at the same time



Benefits

Improve product reliability

Improve usability

Improve consistency across products...



Benefits

Reduce production costs



Reduce certification costs



Shorten time-to-market



Hall of Fame

splc.net/fame.html



BOSCH

Invented for life



PHILIPS



NOKIA
Connecting People

CelsiusTech

ERICSSON



Lucent Technologies
Bell Labs Innovations



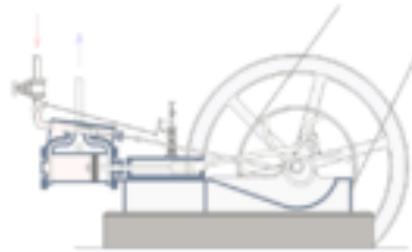


Printer Firmware

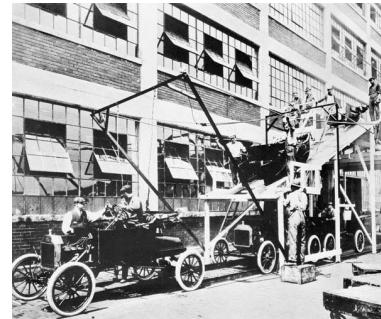
- Production cost reduced by 75%
- Development time reduced by 33%
- Reported defects reduced by 96%



A Bit of History: Industrial Revolution



1698
Thomas Savery



1901
Henry Ford



1980s

Nowaday: Product Lines Everywhere



Product Lines of Cars



This image may contain optional equipment. [360°](#)

Agila, Club
1.2i 16v, 5 Speed
Blaze Red, Melt / Elba Charcoal
Total € 15,684.00

[Exterior](#) | [Interior](#) [Side](#) | [Front](#) | [Rear](#) [360°](#)

[1. Trims/Series](#) | [2. Engine/Transmission](#) | [3. Colour & Style](#) | [4. Options](#) | [5. Summary](#) [Next Step](#)

Choose Your Options

<input type="checkbox"/> CD 30	Standard	- MP3 CD player with MP3 format, stereo radio, steering wheel mounted audio controls
<input checked="" type="checkbox"/> Air conditioning	€ 923.00	
<input checked="" type="checkbox"/> Electronic Stability Programme (ESP)	€ 411.00	
<input checked="" type="checkbox"/> Emergency tyre inflation kit in lieu of space-saver spare wheel and tyre	Standard	

[Audio/Comms/Nav](#) | [Heating/Ventilation](#) | [Mechanical](#) | [Safety/Security](#) | [A-Z](#)

[Next Step: Summary](#)

Pricing Details

Club	€ 14,350.00
1.2i 16v, 5 Speed	
Blaze Red	€ 0.00
Melt / Elba Charcoal	€ 0.00
15-inch steel wheels with 185/60 R 15 tyres and flush wheel covers	€ 0.00
Options (2)	
You selected:	
<input checked="" type="checkbox"/> Air conditioning	€ 923.00
<input checked="" type="checkbox"/> Electronic Stability Programme (ESP)	€ 411.00
Total	€ 15,684.00

Legend

- Selected Option
- Selectable Option
- Option contained in an option pack
- Option contained in an option pack or standard equipment which has been replaced by another option
- Option that is only selectable together with another option. Please click for details

Willkommen bei selve - the shoe individualizer

http://www.selve.net/index_js.html

KOLLEKTION FUSSTYP MYSELVE INFO HOME selve

MODELLE
LOOKBOOK

SELVE-ID
PASSWORD
>>ANMELDEN

selve Kollektion -> Style: casuals -> Modell: Opal

modell-details >> hier clicken

>>SELVE SCHUHREGAL Inhalt:0

>>SHOPPING BAG Inhalt:0

A. Erstes Oberleder
 Veloursleder Sand
 Veloursleder Bordeaux
 Veloursleder Cognac
 Veloursleder Sand
 Putzenleder
 Beige

B. Absatz
 Hufeisen Braun

C. Sohle
 Gummisoehle

>>AENDERN
 >>ZURUECKLEGEN

The screenshot shows a web-based shoe customization tool. On the left, there's a sidebar with icons for a shoe rack (containing 0 items) and a shopping bag (also containing 0 items). The main area displays a pair of light-colored oxford-style shoes with dark green accents. Above the shoes, a callout box labeled 'modell-details' with an arrow icon says '>> hier clicken'. To the right of the shoes is a list of customization options with dropdown menus:

- A. Erstes Oberleder:** Veloursleder Sand (selected), Veloursleder Bordeaux, Veloursleder Cognac, Veloursleder Sand, Putzenleder, Beige.
- B. Absatz:** Hufeisen Braun.
- C. Sohle:** Gummisoehle.

At the bottom right of the customization area are two buttons: '>>AENDERN' and '>>ZURUECKLEGEN'.

Müsli individuell online mixen! Bio-Müsli. - Mozilla Firefox

File Edit View History Bookmarks Tools Help

m http://www.mymuesli.com/muesli/index.php?vw=mixer&ec=step1&mnid=1&mnpt=1&type=t0 softwareproduktlinien ABP SIE

Müsli individuell online mixen! Bio-M... +

mymuesli custom-mixed cereals

muesli mixer blog fragen about us

Müslibasis Basis verfeinern Früchte Nüsse & Kerne Extras

Früchte

Köstliche Bio-Trockenfrüchte, müsligerecht aufbereitet. Du kannst eine Frucht auch mehrmals auswählen, um deren Anteil zu steigern.

Ananas
lecker, exotisch und wunderbar | 0.65€ (30g)
[mehr Infos](#)

Apfelstücke
Ohne Worte weil Klassiker | 0.45€ (25g)
[mehr Infos](#)

Aprikosen

hoch ▲ ▼ runter

Apfelstücke
Buchweizenflocken
C'Mohn, baby!

Nährwerte pro 100g ▲
575g nur 4,70€
entspricht 8,17€/kg
inkl. MWSt., zzgl. Versandkosten

fertig gemixt?
weiter

Done en-US

Der Dell Online-Shop: Stellen Sie Ihr eigenes System zusammen - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

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Grafikkarte

128 MB nVidia NVS285 DVI/VGA-Grafikkarte

Auswahlhilfe

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- 256 MB nVidia Quadro FX3450-Grafikkarte [plus 547,40 € oder 17 €/Monat¹]
- 128 MB nVidia NVS285 DVI/VGA-Grafikkarte [Im Preis enthalten]
- Grafikkarte PCIe x16 (DVI/VGA) Matrox QID LP PCIe, 128 MB, DVI- oder VGA-Grafikkarte für 4 Monitore [plus 630,70 € oder 20 €/Monat¹]
- 128 MB ATI Fire GL V3400-Grafikkarte [plus 44,03 € oder 1 €/Monat¹]

Festplatte

80 GB Serial ATA-II-Festplatte (7.200 U/min) mit NCQ

Auswahlhilfe

- 160 GB Serial ATA-II-Festplatte (7.200 U/min) mit NCQ [plus 16,66 €]
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Dell Precision™ 390 Essential (W06390xp)

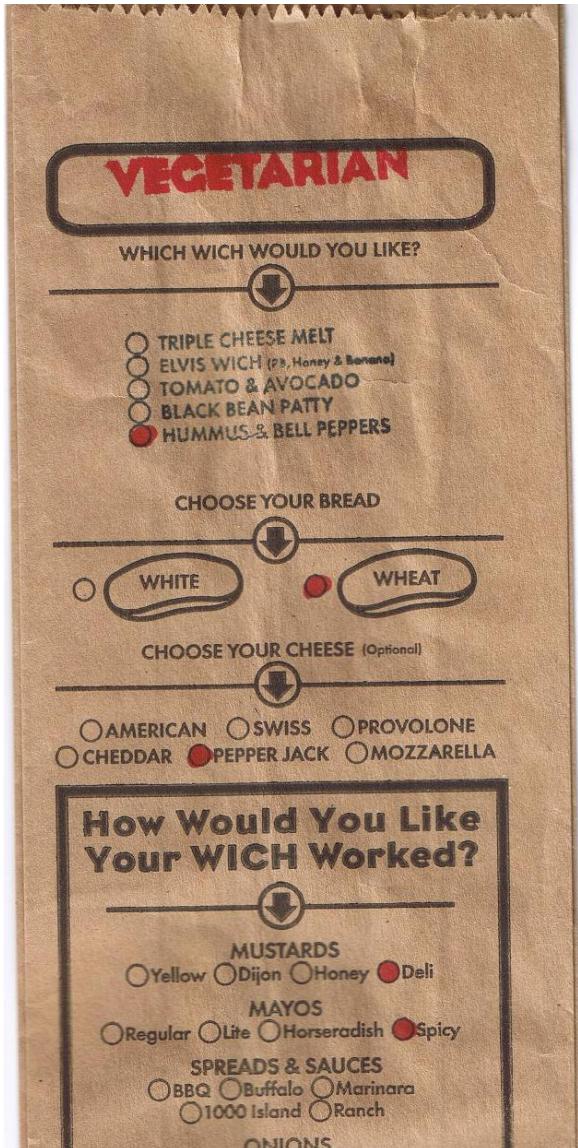
inkl. MwSt., zzgl. 19,04 € Versand
Ermäßiger Sonderpreis
913,92 € Es gelten keine zusätzlichen Preismarkierungen. Das Angebot gilt für maximal 5 Systeme

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Transferring data from i.dell.com...

Food? Product lines!

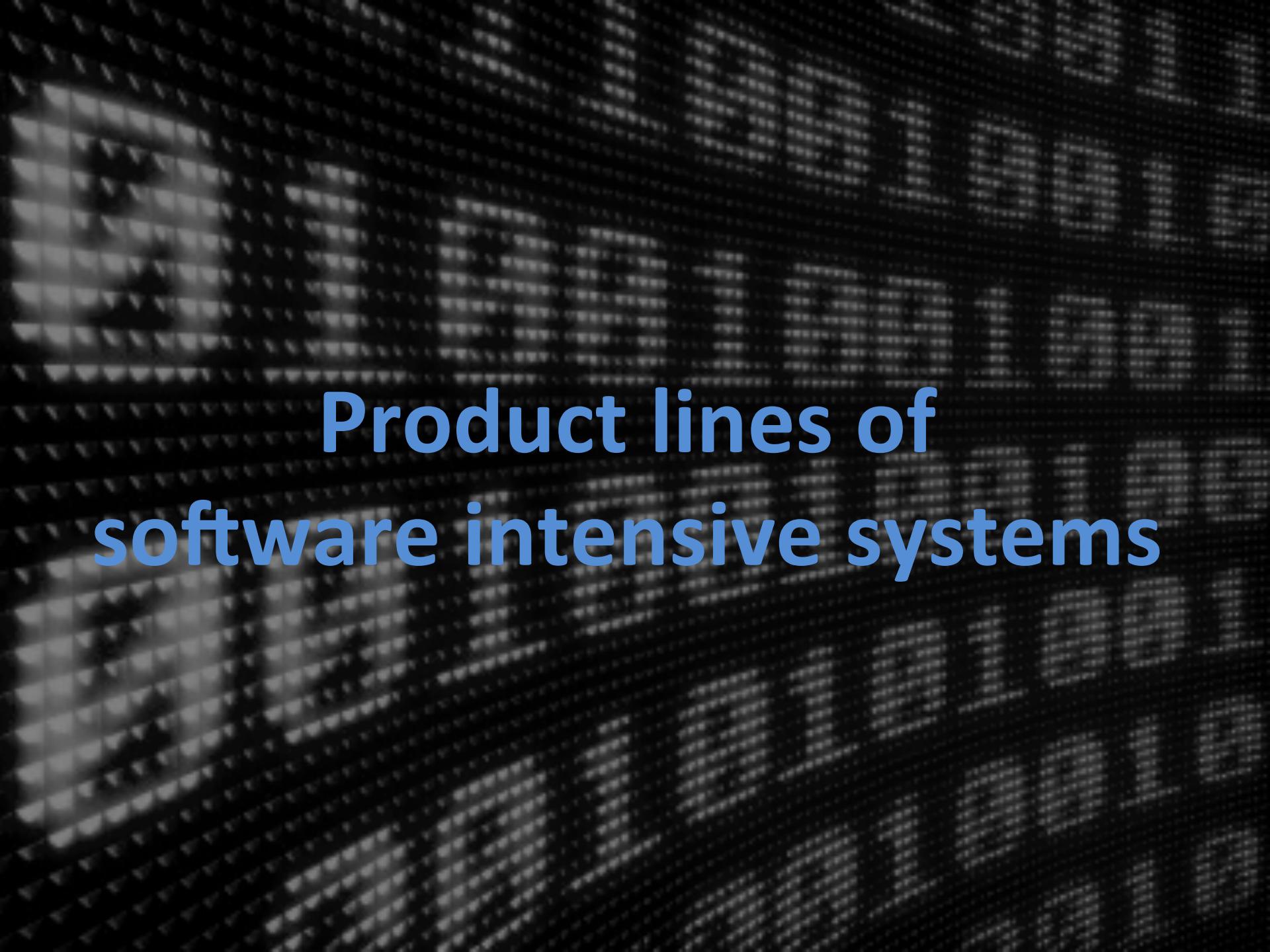






Mass production

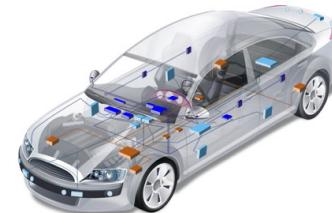
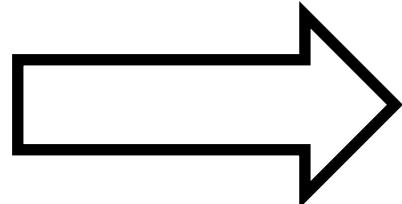
**What about
software?**



**Product lines of
software intensive systems**

Software intensive systems

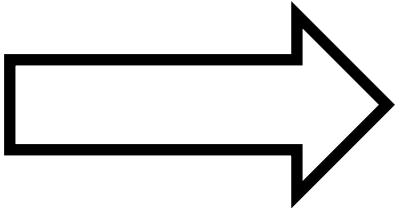
are declined in many variants





Software intensive systems

are declined in many variants



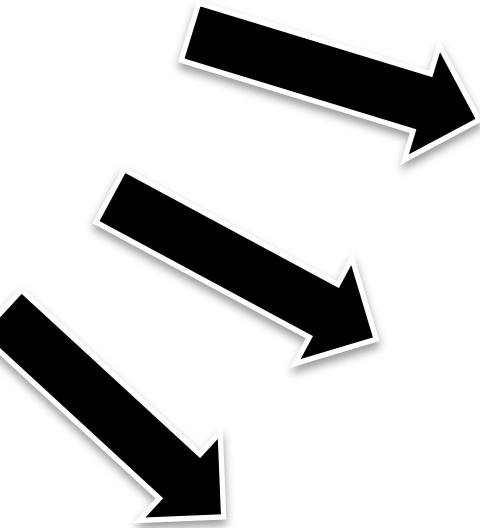
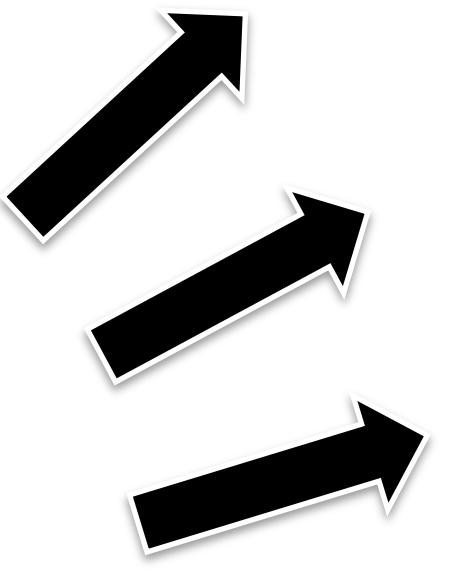
Software Product Lines



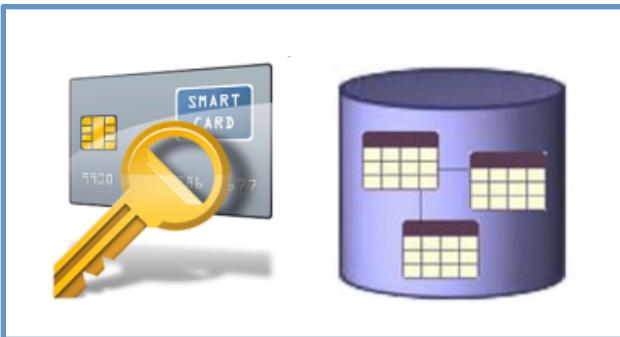
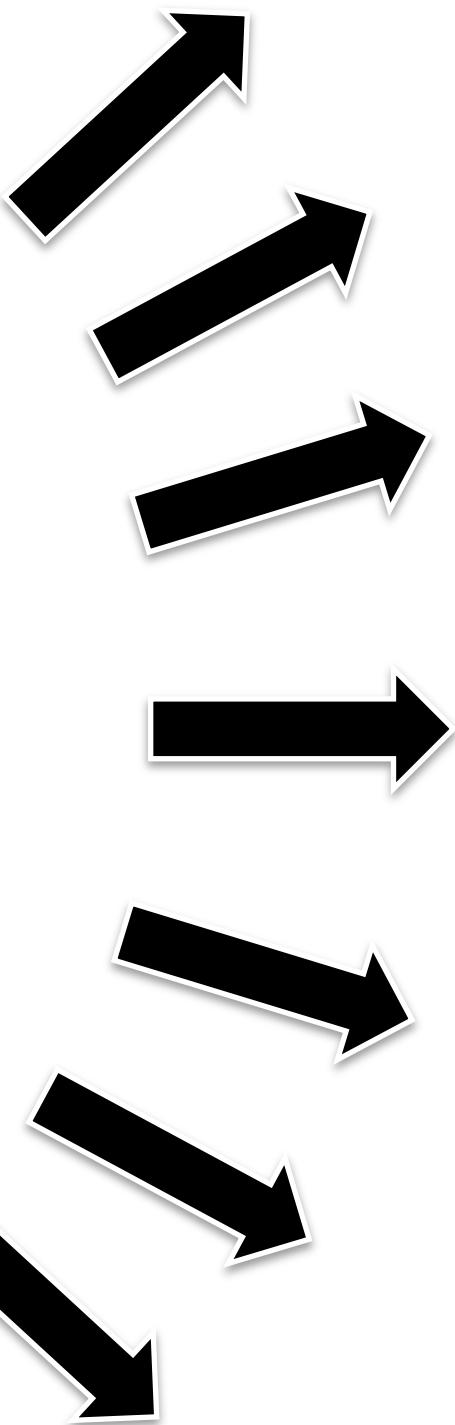
01011011
110111110
001101110
110011101
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10001010
10101011
000011110
11010101
110111010
011000100
01010101
110101110
101010101



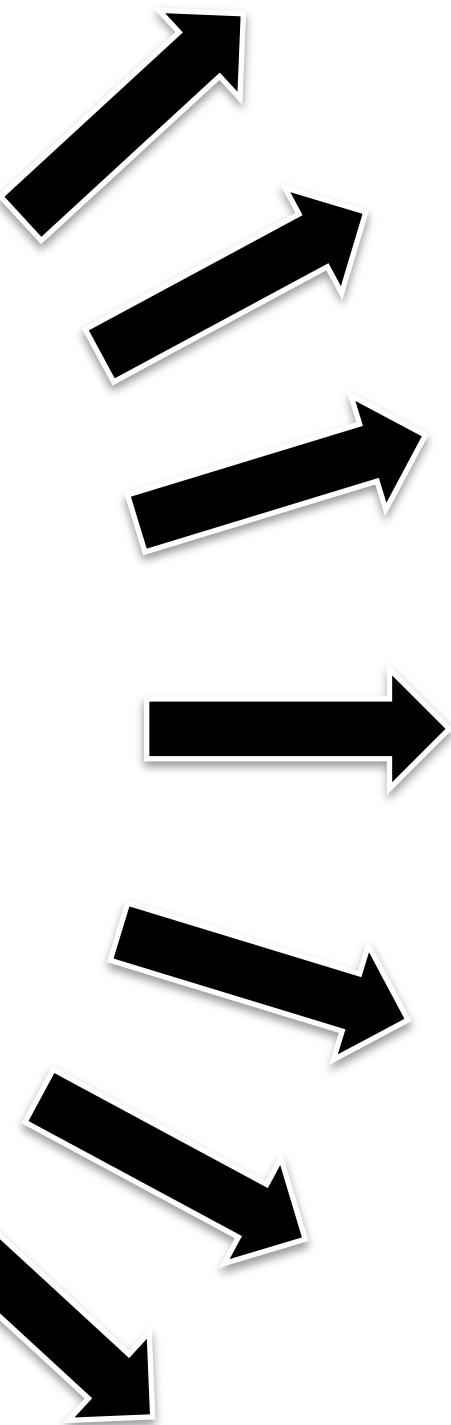
Car



Database Engine

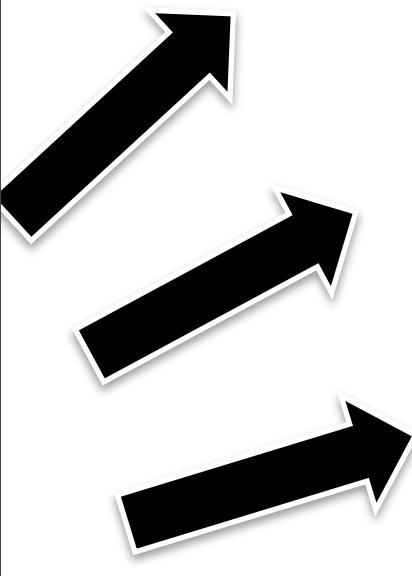


Printer Firmware

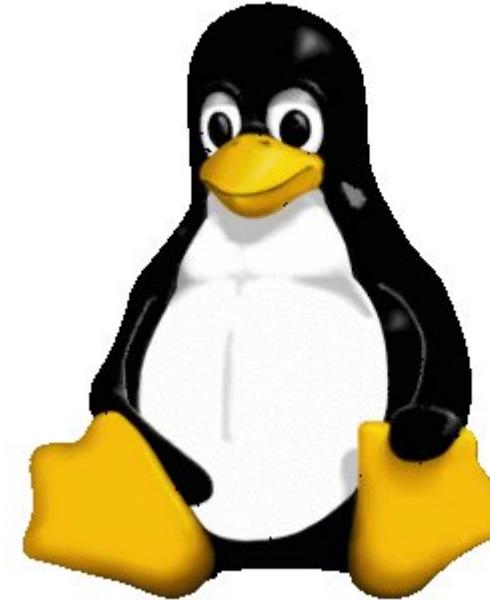


```
1 karmad 2 karmas Encoding: iso-8859-1 generic .config - Linux Kernel v2.6.33.3 Configuration Processor type and features Arrow keys navigate the menu. <Enter> selects submenus -->. Highlighted letters are hotkeys. Pressing <> includes, <> excludes, <M> modularizes features. Press <Esc><Esc> to exit, <?> for Help, </> for Search. Legend: [*] built-in [ ] excluded [<> module] < > module capable [ ] Tickless System (Dynamic Ticks) [*] High Resolution Timer Support [ ] SYSPOLLING interrupt handling support [ ] Support for extended (non-PC) x86 platforms [ ] Single-depth ICHAN output [ ] Paravirtualized guest support ... [ ] Memtest [ ] Processor family (Generic-x86-64) --- [ ] Preemption Model (No Forced Preemption (Server)) --- [ ] Renote 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 [ ] 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 64M 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 >
```

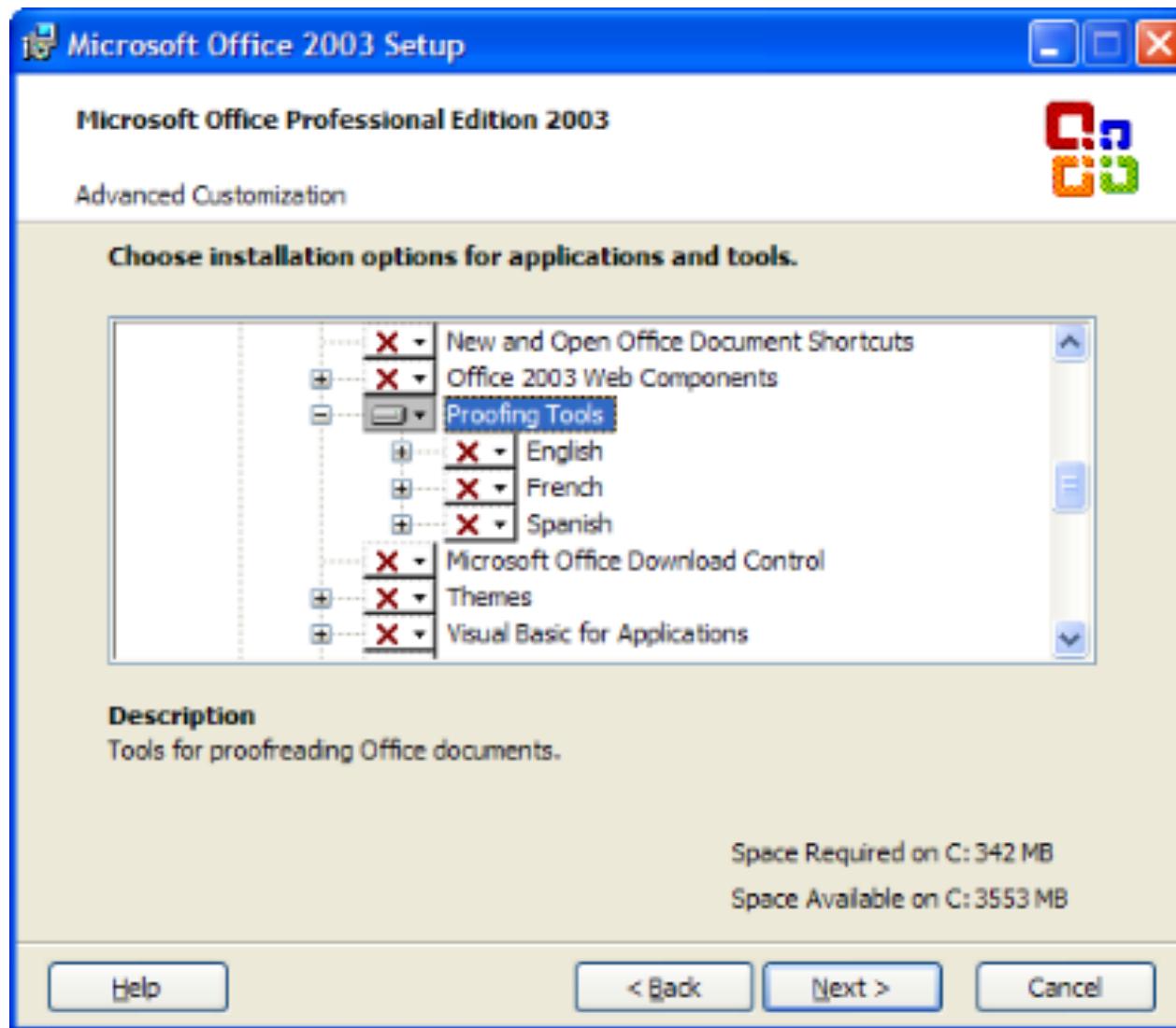
Linux Kernel



Linux-Kernel



Features in Microsoft Office



Bref

bref.
CANAL à 30 ans.

ETAPE 1 : DONNE TON PRENOM

MATHIEU

→ OK

Online Generator

← → C bref30ans.canalplus.fr/#c

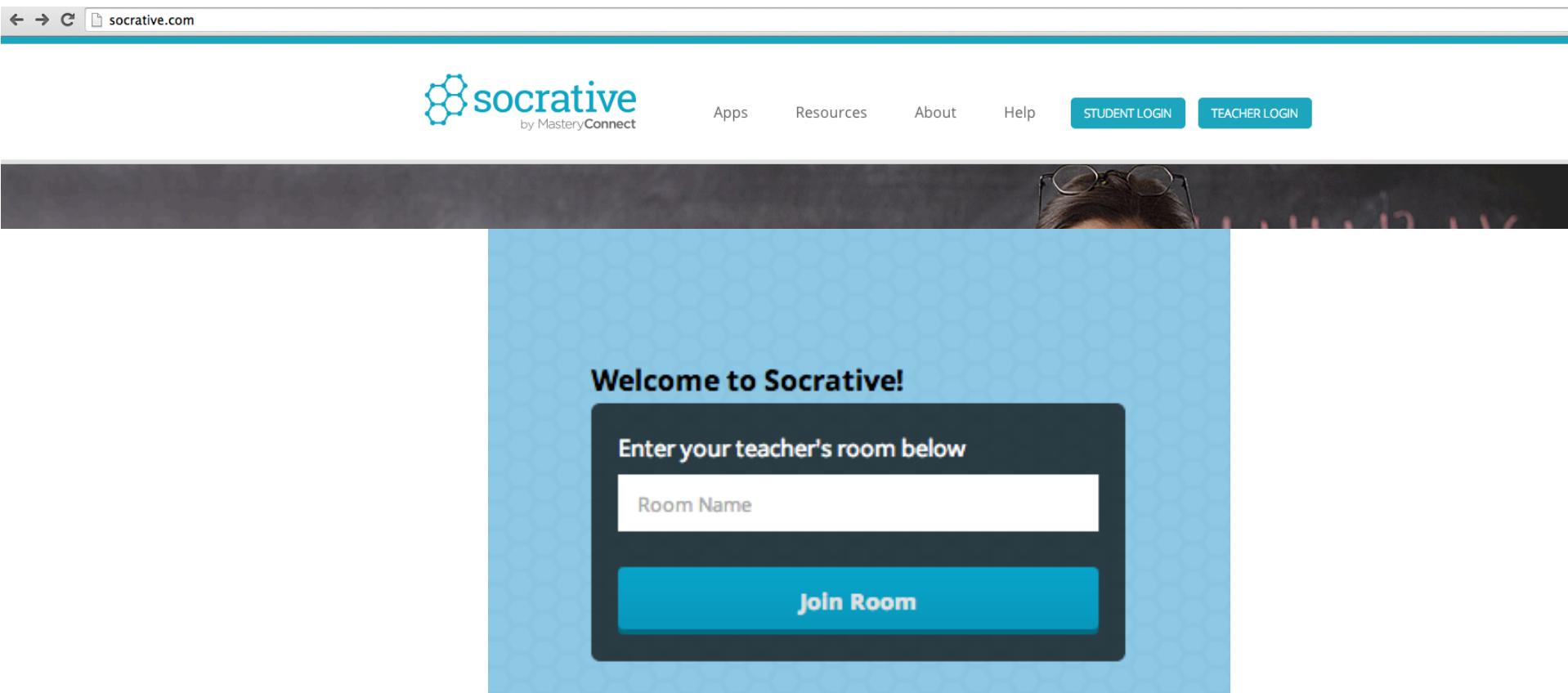
ETAPE 2 : CHOISIS 3 BONS SOUVENIRS



Variant



Quizz Time



A screenshot of a web browser showing the Socrative login page. The URL 'socrative.com' is visible in the address bar. The page features the Socrative logo ('socrative by MasteryConnect') and navigation links for 'Apps', 'Resources', 'About', and 'Help'. Two prominent blue buttons at the top right are 'STUDENT LOGIN' and 'TEACHER LOGIN'. The main content area has a blue hexagonal background and displays the text 'Welcome to Socrative!' above a dark input field. Inside the field, it says 'Enter your teacher's room below' and contains a white input box labeled 'Room Name'. A large blue button at the bottom of the field is labeled 'Join Room'.

e9a8d603

Quizz Time

e9a8d603

Give three examples of software product lines
(also called configurable systems or variability-intensive systems)

Variability

“the ability of a system to be efficiently extended, changed, customized or configured for use in a particular context”

Mikael Svahnberg, Jilles van Gurp, and Jan Bosch (2005)



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

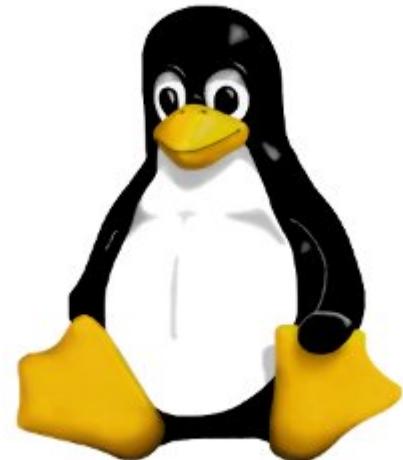
320^{optional, independent}
features

more variants than estimated
atoms in the universe



2000 features

10000
features

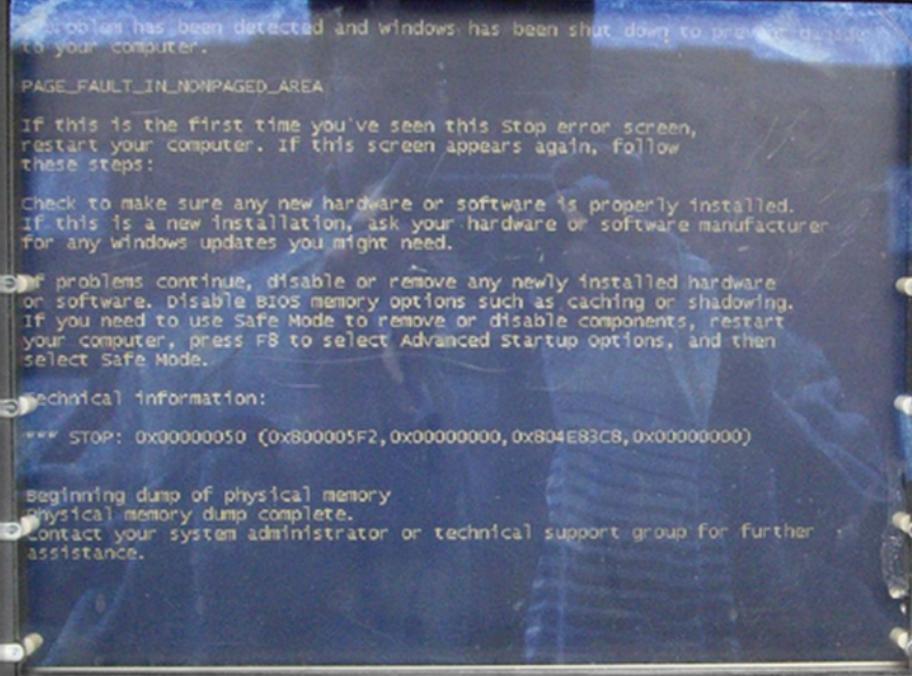


Automation?

Avoid solving the same problem!

2, 3...n times

Correctness



1 2 ABC 3 DEF
4 GHI 5 JKL 6 MNO
CLEAR

A photograph of a residential street during construction. In the center, a white Link-Belt excavator is positioned on the sidewalk, facing away from the camera. A red utility truck is parked behind it. The road is partially closed with orange traffic cones and a barrier. A silver car is driving away from the viewer on the right side of the road. The background shows houses, trees, and a clear sky.

Maintenance?
Comprehension?

Checking Products



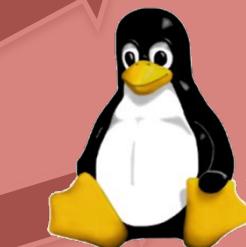
2000 Features
100 Printers
30 New Printers per Year

Printer
Firmware



Linux
Kernel

Checking Products



8000 Features
? Products



The development of a
family of software systems

differs from the development of
a **single** software system

**THANKS CAPTAIN
OBVIOUS**



« The development of a
family of software systems
differs from the development of
a **single** software system »

Reuse

Commonality

Customization

Variability

Automation

A photograph of a car assembly line. In the foreground, a worker wearing a white shirt and red overalls is working on the interior of a silver car. The car's front door is open. Behind the worker, several other cars are lined up on the assembly line. The background shows the industrial interior of a factory with various equipment and a digital display showing the number "042 066 002".

Assembly Line and Mass Customization



Reuse and Mass Customization



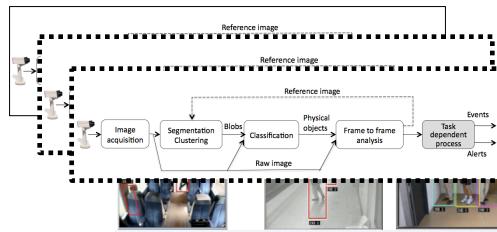
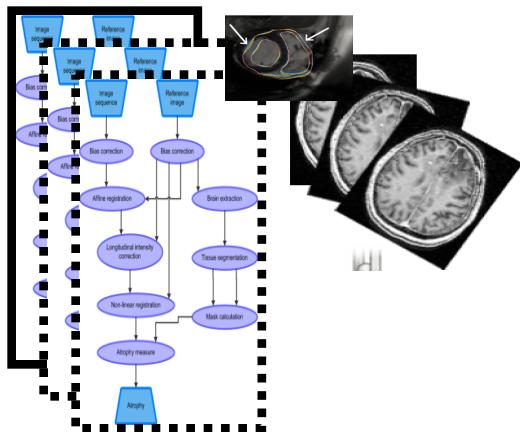
Starting from scratch?

A wide-angle photograph of a massive aircraft assembly facility. In the foreground, several aircraft fuselages are visible, some with their tails pointing towards the viewer and others further back. The floor is a complex network of grey concrete and yellow safety markings. To the left, a large office area with many cubicles and workers is visible. The background features a massive steel truss roof supported by multiple levels of walkways and stairs, with numerous bright overhead lights illuminating the space.

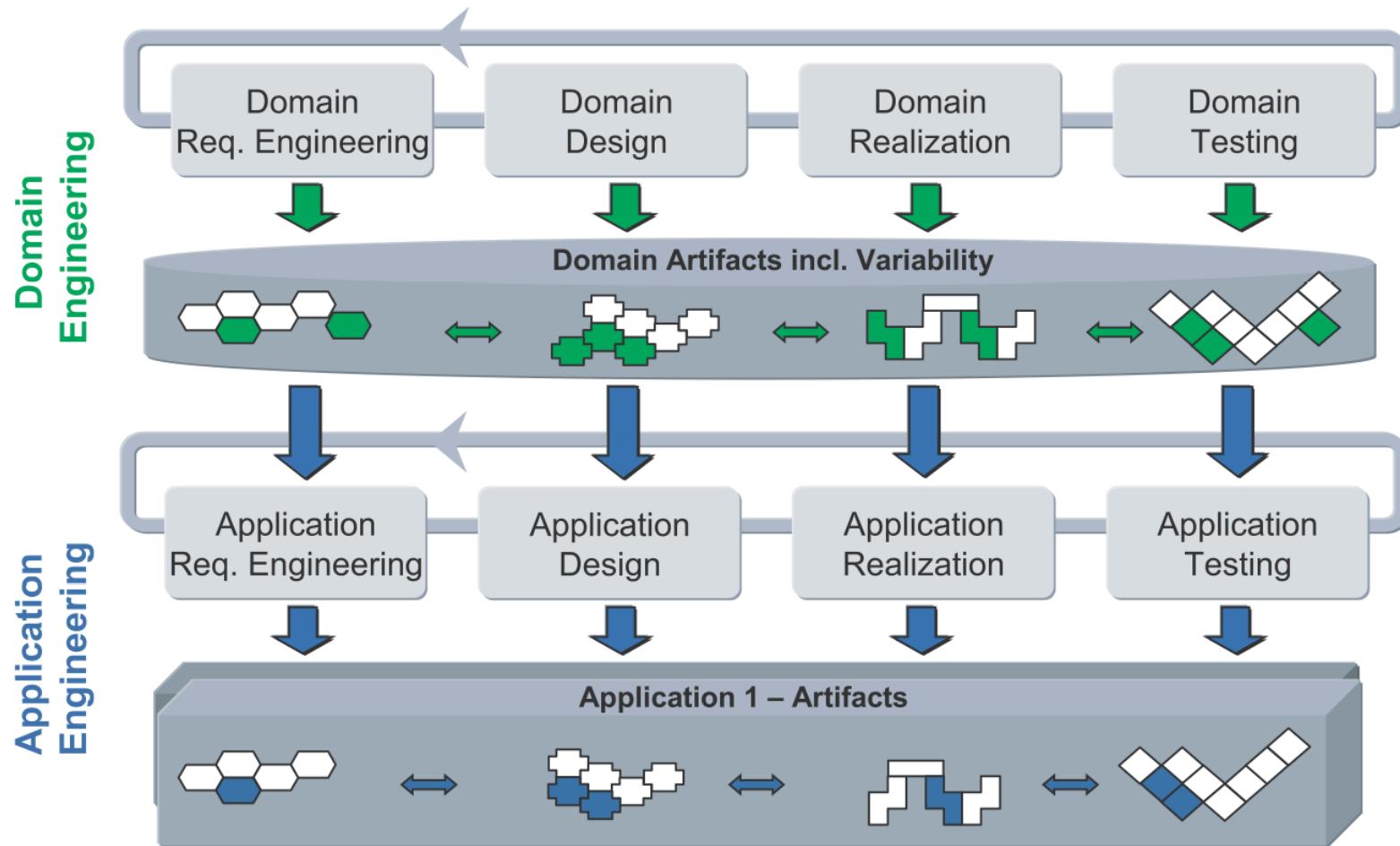
You cannot start from scratch

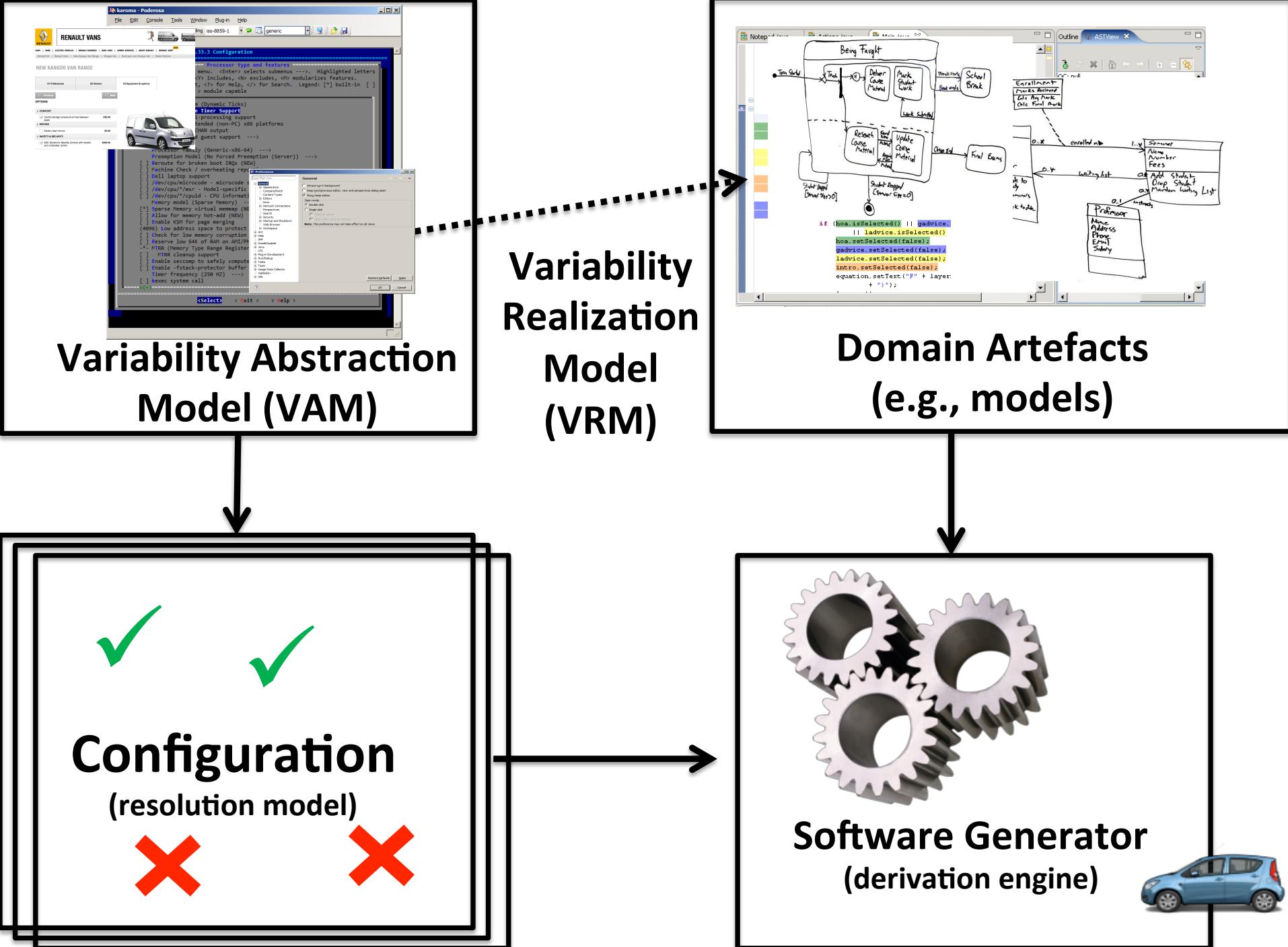
“a set of software- intensive systems that share a common, managed set of features satisfying the specific needs of a particular market segment or mission and that are developed from a common set of core assets in a prescribed way” [Clements et al., 2001]

Software Product Lines



Software Product-Line Engineering





Mapping: an example

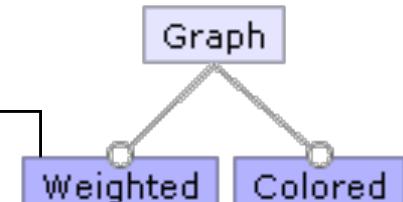
```
class Graph {  
    Vector nv = new Vector(); Vector ev = new Vector();  
    Edge add(Node n, Node m) {  
        Edge e = new Edge(n, m);  
        nv.add(n); nv.add(m); ev.add(e);  
        e.weight = new Weight();  
        return e;  
    }  
    Edge add(Node n, Node m, Weight w)  
    Edge e = new Edge(n, m);  
    nv.add(n); nv.add(m); ev.add(e);  
    e.weight = w; return e;  
}  
void print() {  
    for(int i = 0; i < ev.size(); i++) {  
        ((Edge)ev.get(i)).print();  
    }  
}
```

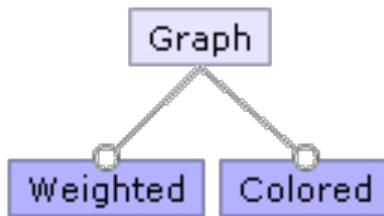
```
class Node {  
    int id = 0;  
    Color color = new Color();  
    void print() {  
        Color.setDisplayColor(color);  
        System.out.print(id);  
    }  
}
```

```
class Edge {  
    Node a, b;  
    Color color = new Color();  
    Weight weight = new Weight();  
    Edge(Node _a, Node _b) { a = _a; b = _b; }  
    void print() {  
        Color.setDisplayColor(color);  
        a.print(); b.print();  
        weight.print();  
    }  
}
```

```
class Color {  
    static void setDisplayColor(Color c) { ... }  
}
```

```
class Weight { void print() { ... } }
```





```

class Graph {
    Vector nv = new Vector(); Vector ev = new Vector();
    Edge add(Node n, Node m) {
        Edge e = new Edge(n, m);
        nv.add(n); nv.add(m); ev.add(e);
        /*if[WEIGHT]*/
        e.weight = new Weight();
        /*end[WEIGHT]*/
        return e;
    }
    /*if[WEIGHT]*/
    Edge add(Node n, Node m, Weight w)
        Edge e = new Edge(n, m);
        nv.add(n); nv.add(m); ev.add(e);
        e.weight = w; return e;
    }
    /*end[WEIGHT]*/
    void print() {
        for(int i = 0; i < ev.size(); i++) {
            ((Edge)ev.get(i)).print();
        }
    }
}

/*if[WEIGHT]*/
class Weight { void print() { ... } }
/*end[WEIGHT]*/

```

```

class Edge {
    Node a, b;
    /*if[COLOR]*/
    Color color = new Color();
    /*end[COLOR]*/
    /*if[WEIGHT]*/
    Weight weight;
    /*end[WEIGHT]*/
    Edge(Node _a, Node _b) { a = _a; b = _b; }
    void print() {
        /*if[COLOR]*/
        Color.setDisplayColor(color);
        /*end[COLOR]*/
        a.print(); b.print();
        /*if[WEIGHT]*/
        weight.print();
        /*end[WEIGHT]*/
    }
}

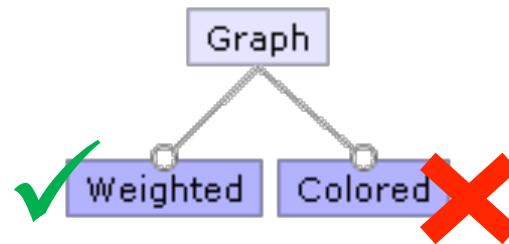
/*if[COLOR]*/
class Color {
    static void setDisplayColor(Color c) { ... }
}
/*end[COLOR]*/

```

```

class Node {
    int id = 0;
    /*if[COLOR]*/
}

```



```

class Graph {
    Vector nv = new Vector(); Vector ev = new Vector();
    Edge add(Node n, Node m) {
        Edge e = new Edge(n, m);
        nv.add(n); nv.add(m); ev.add(e);
        e.weight = new Weight();
        return e;
    }
    Edge add(Node n, Node m, Weight w)
        Edge e = new Edge(n, m);
        nv.add(n); nv.add(m); ev.add(e);
        e.weight = w; return e;
    }
    void print() {
        for(int i = 0; i < ev.size(); i++) {
            ((Edge)ev.get(i)).print();
        }
    }
}
    
```

```

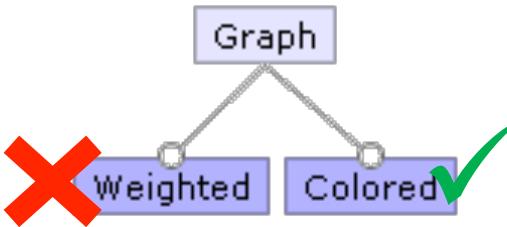
class Edge {
    Node a, b;
    Weight weight;
    Edge(Node _a, Node _b) { a = _a; b = _b; }
    void print() {
        a.print(); b.print();
        weight.print();
    }
}
    
```

```

class Node {
    int id = 0;
    void print() {
        System.out.print(id);
    }
}
    
```

```

class Weight { void print() { ... } }
    
```



```

class Graph {
    Vector nv = new Vector(); Vector ev = new Vector();
    Edge add(Node n, Node m) {
        Edge e = new Edge(n, m);
        nv.add(n); nv.add(m); ev.add(e);
    return e;
    }
    void print() {
        for(int i = 0; i < ev.size(); i++) {
            ((Edge)ev.get(i)).print();
        }
    }
}
  
```

```

class Edge {
    Node a, b;
    Color color = new Color();
    Edge(Node _a, Node _b) { a = _a; b = _b; }
    void print() {
        Color.setDisplayColor(color);
        a.print(); b.print();
    }
}
  
```

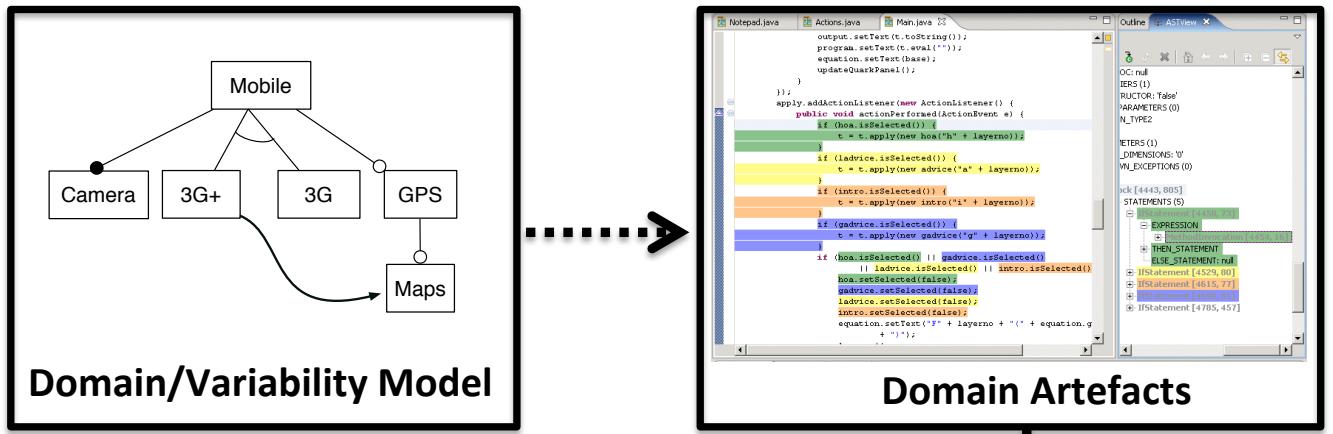
```

class Color {
    static void setDisplayColor(Color c) { ... }
}
  
```

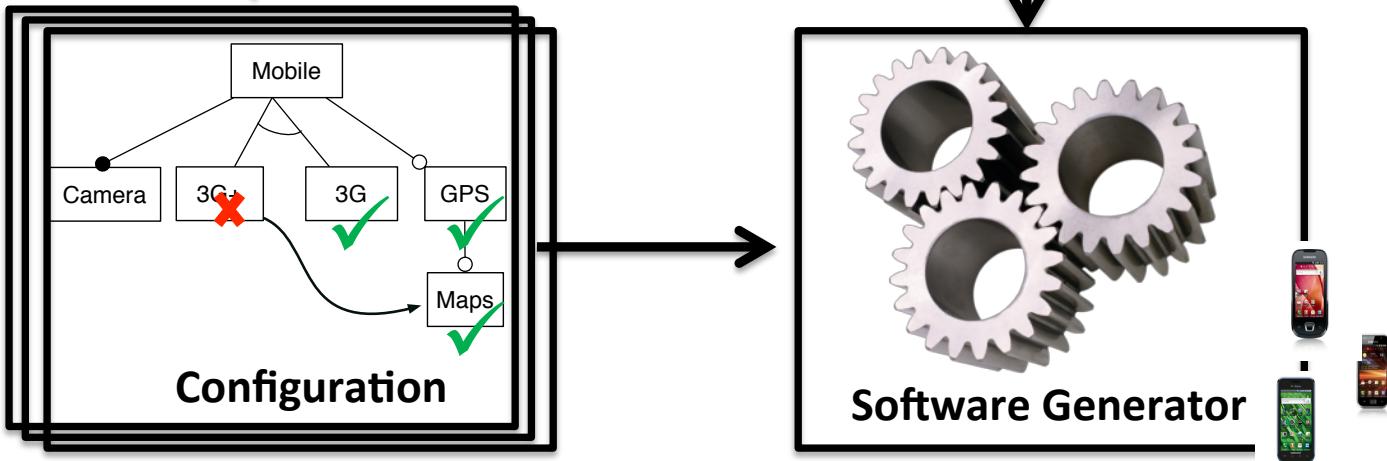
```

class Node {
    int id = 0;
    Color color = new Color();
    void print() {
        Color.setDisplayColor(color);
        System.out.print(id);
    }
}
  
```

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)

Software Product Line and Variability Engineering

A revisit of your cursus

What is new?

Family vs single systems

Focus on reuse

Domain engineering

Factoring out commonality

Managing variability

« variability »

Is it really new?

Parameter

```
Administrator: C:\Windows\system32\cmd.exe
C:\Users\kaestner.INFORMATIK.000>dir /?
Displays a list of files and subdirectories in a directory.

DIR [drive:][path][filename] [/A[[:l]attributes] [/B] [/C] [/D] [/L] [/N]
  [/O[[:l]sortorder]] [/P] [/Q] [/R] [/S] [/T[[:l]timefield]] [/W] [/X] [/4]

[drive:][path][filename]
      Specifies drive, directory, and/or files to list.

/A          Displays files with specified attributes.
attributes   D  Directories                  R  Read-only files
              H  Hidden files                A  Files ready for archiving
              S  System files                I  Not content indexed files
              L  Reparse Points             -  Prefix meaning not
/B          Uses bare format (no heading information or summary).
/C          Display the thousand separator in file sizes. This is the
            default. Use /-C to disable display of separator.
/D          Same as wide but files are list sorted by column.
/L          Uses lowercase.
/N          New long list format where filenames are on the far right.
/O          List by files in sorted order.
sortorder    N  By name (alphabetic)        S  By size (smallest first)
              E  By extension (alphabetic)  D  By date/time (oldest first)
              G  Group directories first   -  Prefix to reverse order
/P          Pauses after each screenful of information.
```

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
```

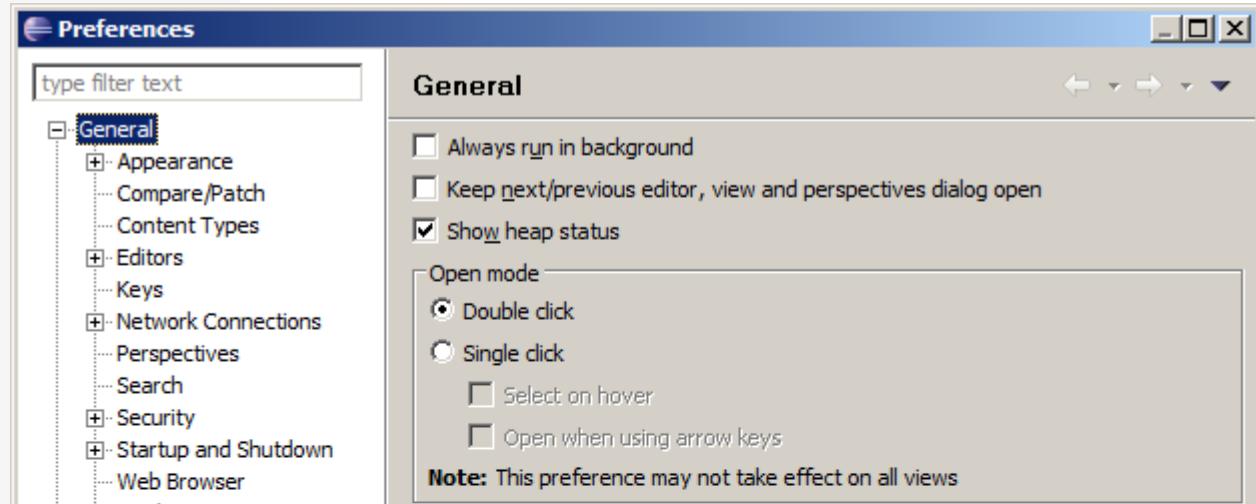
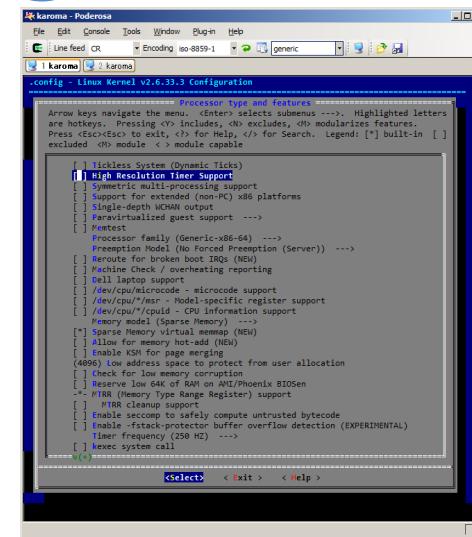
```
HostnameLookups Off
```

```
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

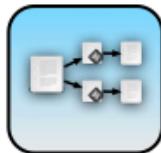
Code Cloning (example, Linux driver)

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

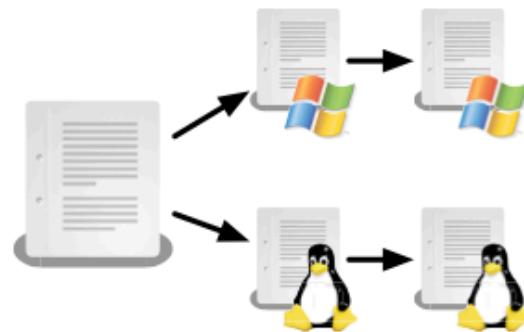


Clone to reuse and adapt existing solutions

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

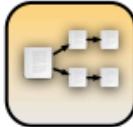


Platform Variations

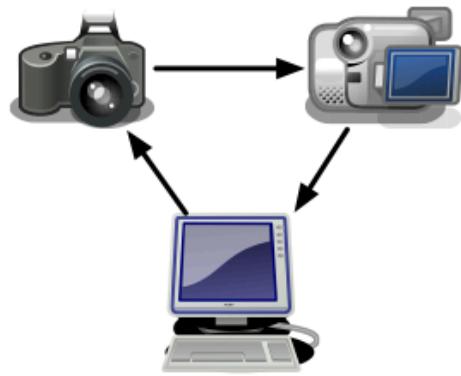


**Clone existing code and fix
low level platform interaction**

- + 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

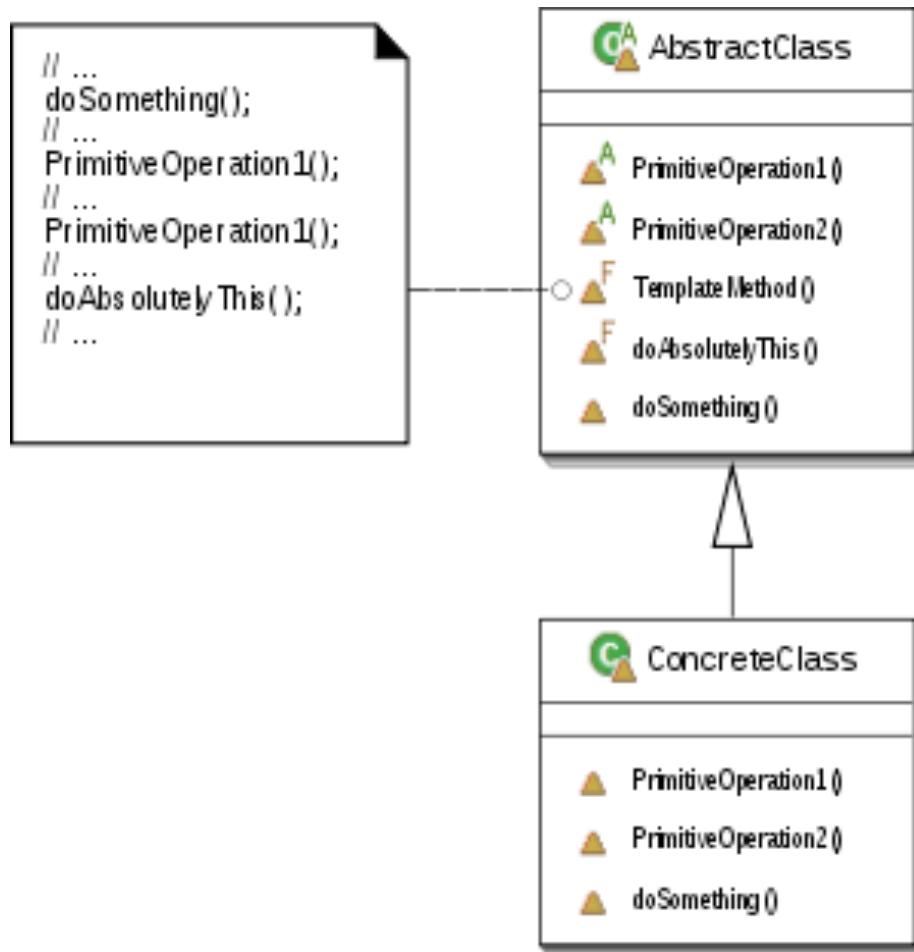
Factory

Strategy

Decorator

....

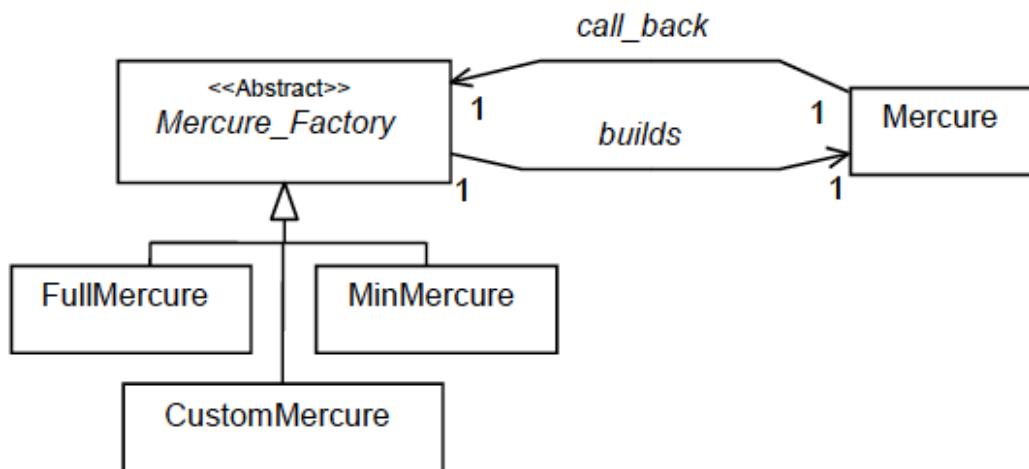
Template Method



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

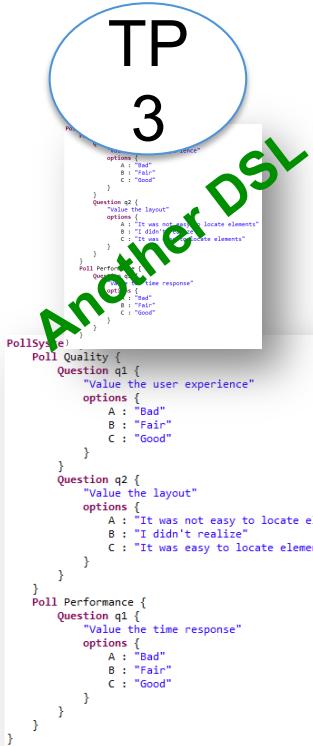
Plugin-based systems

(Active) Annotations

can have parameters

Metamodeling and Domain-Specific Languages

Commonalities



Model-to-Model

TP 4

Pivot
MM

TP 3

UI
model



Model-to-Text

Generator
TP 5



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

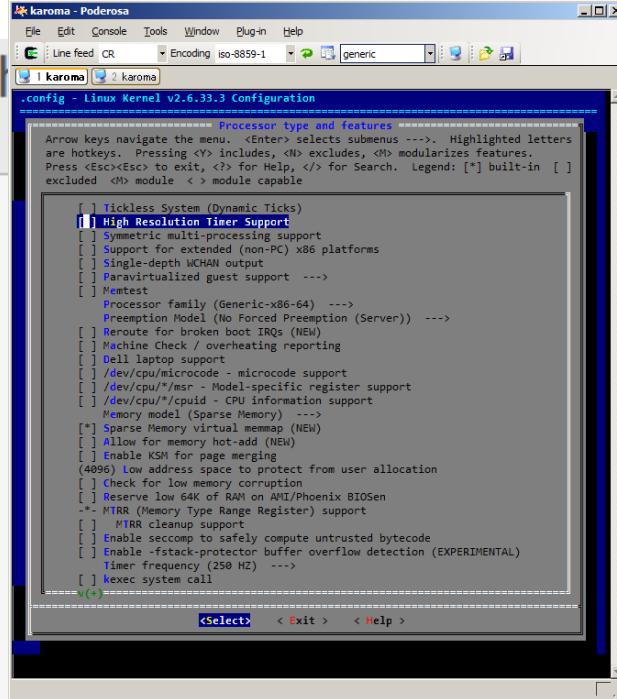
ErrorLog logs/error.log
LogLevel error

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 is a breadcrumb trail: 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 shows 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, there is an image of a white Renault Kangoo van.

A screenshot of the Eclipse IDE. The central part shows a code editor with Java code for 'Notepad.java', 'Actions.java', and 'Main.java'. The code includes various imports and logic involving 'hoa', 't', 'gadvice', and 'intro' objects. The 'ASTView' panel on the right displays the abstract syntax tree (AST) for the selected code, showing nodes for statements, expressions, and types. The left side of the interface shows the 'Preferences' dialog with the 'General' section open, containing settings for running in background, keeping dialogs open, and showing heap status. A note in the preferences dialog says: 'Note: This preference is not yet supported in the Java perspective'.

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

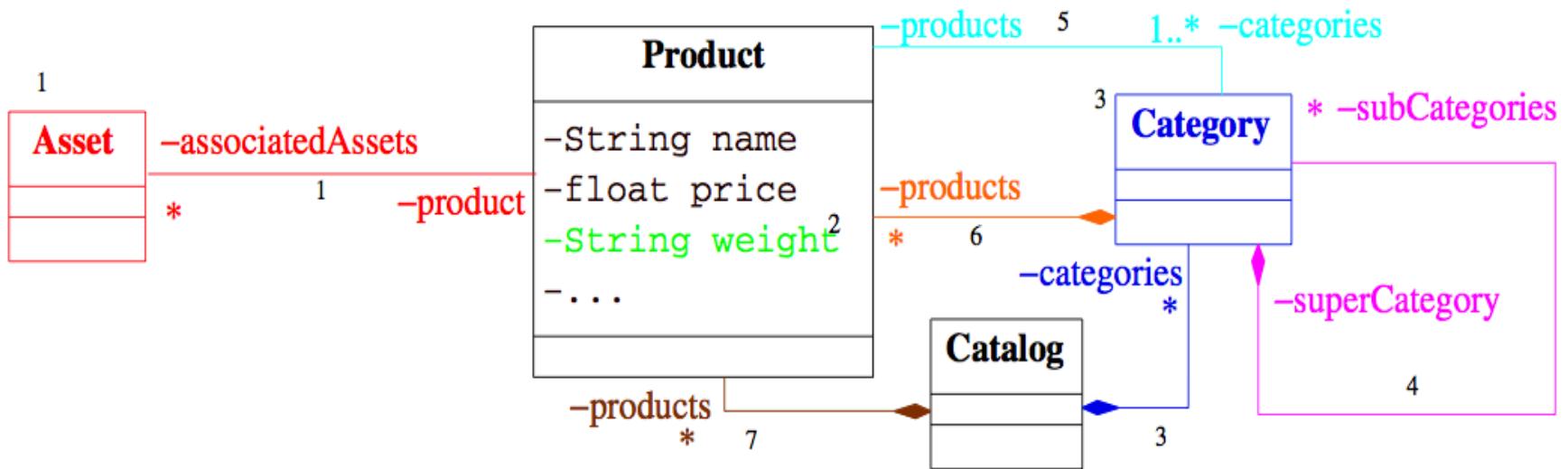


Illegal variant

Domain Design

Presence conditions:

true		MultiLevel		4
AssociatedAssets		MultipleClassification		5
PhysicalGoods		Categories & !MultipleClassification		6
Categories		MultipleClassification !Categories		7



Feature Models

A screenshot of the karmo configuration tool. It shows a list of kernel features with checkboxes. Some features are grouped under titles like "Processor Type and features". A legend at the bottom indicates that checkboxes with a blue border mean "selected", while others mean "excluded".

Variability Model

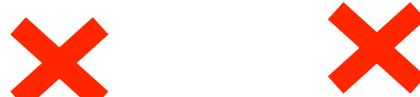


A screenshot of an IDE showing Java code. Annotations are overlaid on the code, color-coded by variable: green for hoa, yellow for ladvice, orange for intro, and blue for gadvice. A separate window titled "ASTView" shows a hierarchical tree of statements, with some nodes highlighted in green, yellow, and orange, corresponding to the annotations in the code.

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



Configuration



is crucial



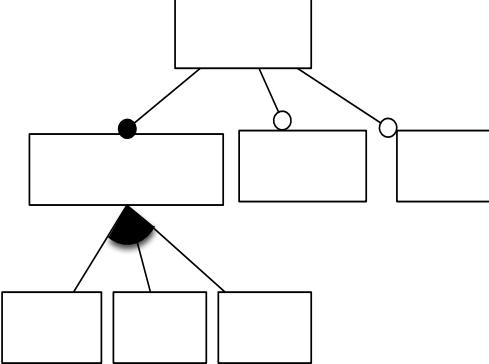
Unused flexibility





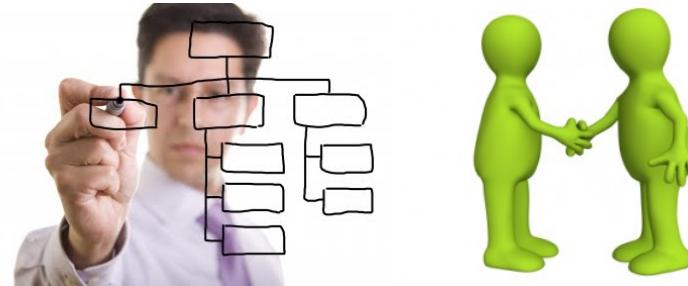
Illegal variant

Feature Model

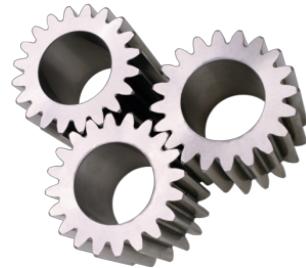


not, and, or, implies

Communicative



Analytic



Generative





R8 Spyder

5.2 FSI quattro R tronic

Prix total

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Prix de base

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Equipements optionnels

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- ▶ 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

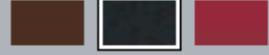


Couleurs personnalisées Audi exclusive



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

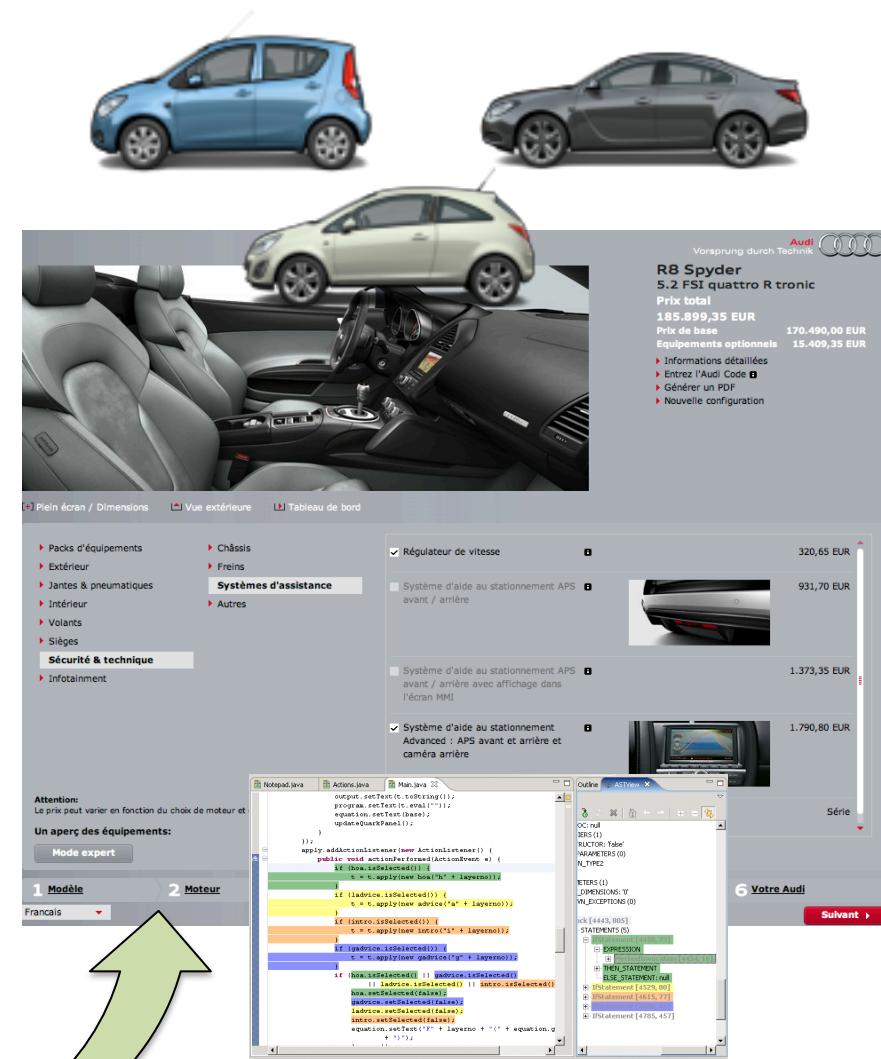
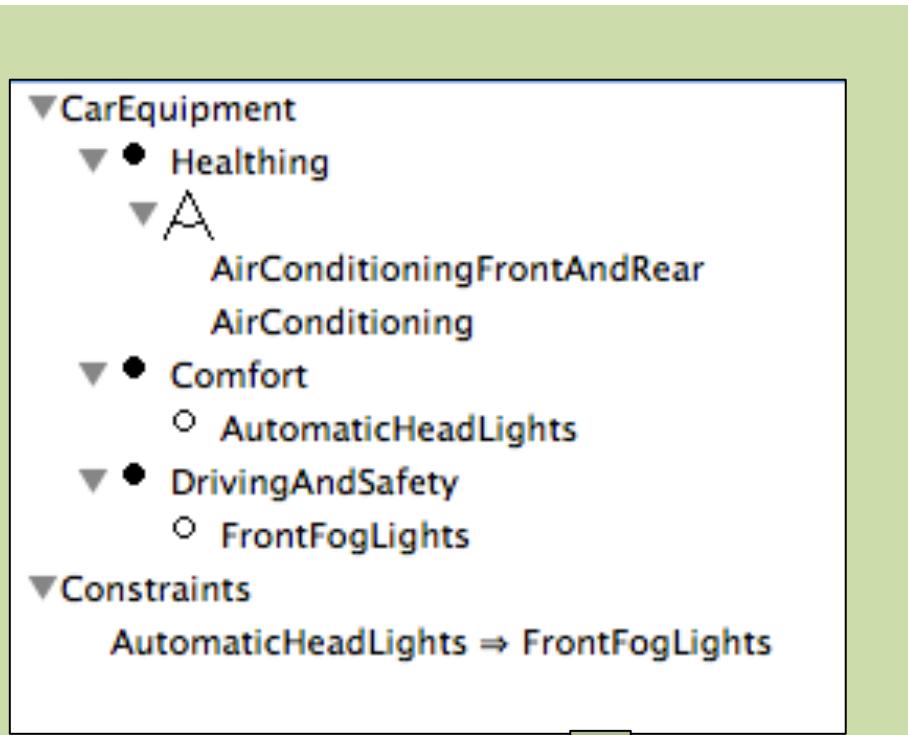
5 Option

6 Votre Audi

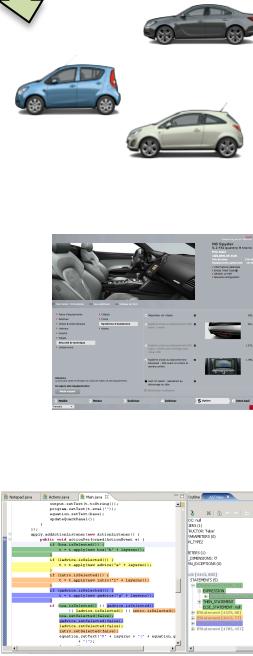
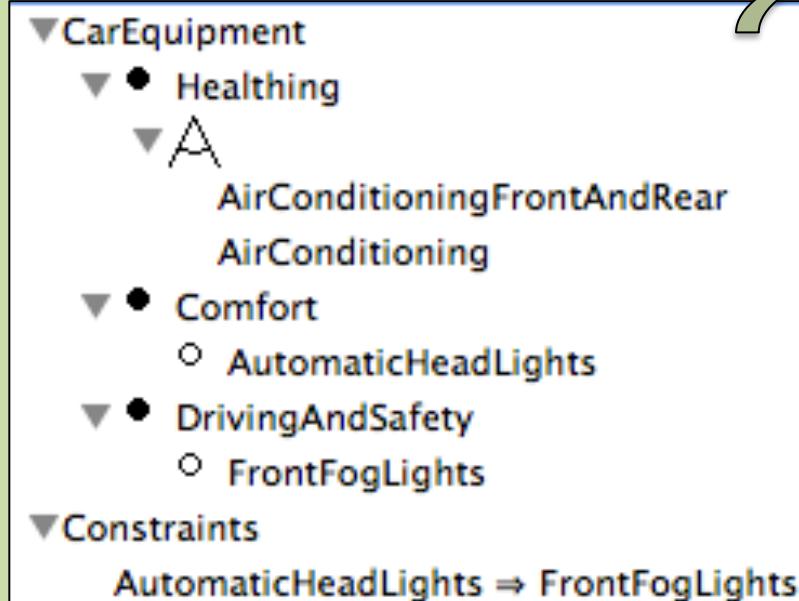
Français ▾

Suivant ▶

Feature Models



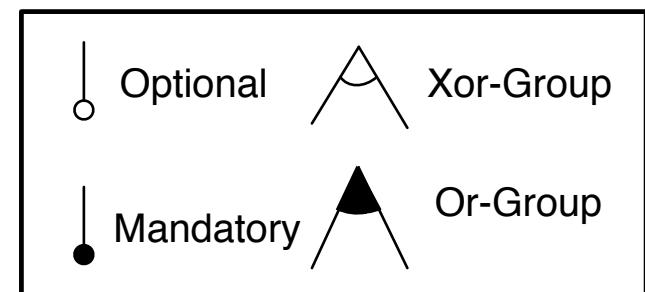
Feature Models (Background)

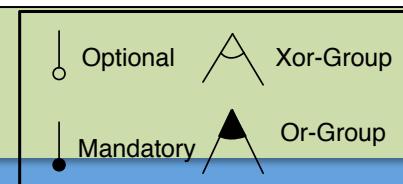
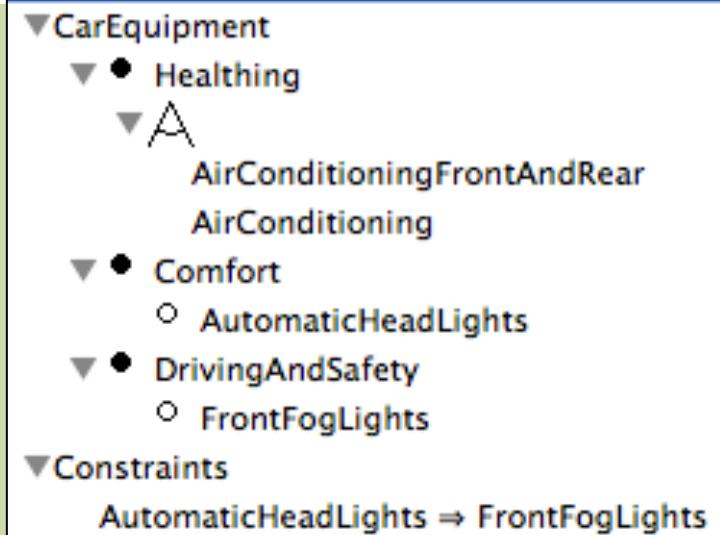
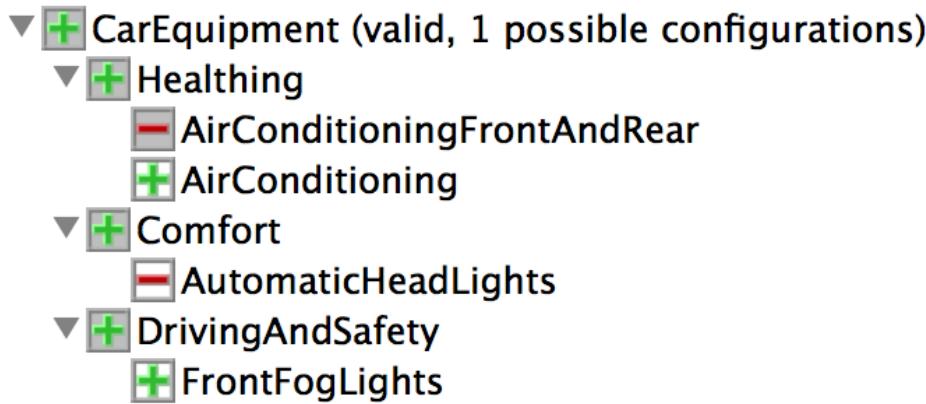


Hierarchy: rooted tree

Variability:

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





Hierarchy + Variability

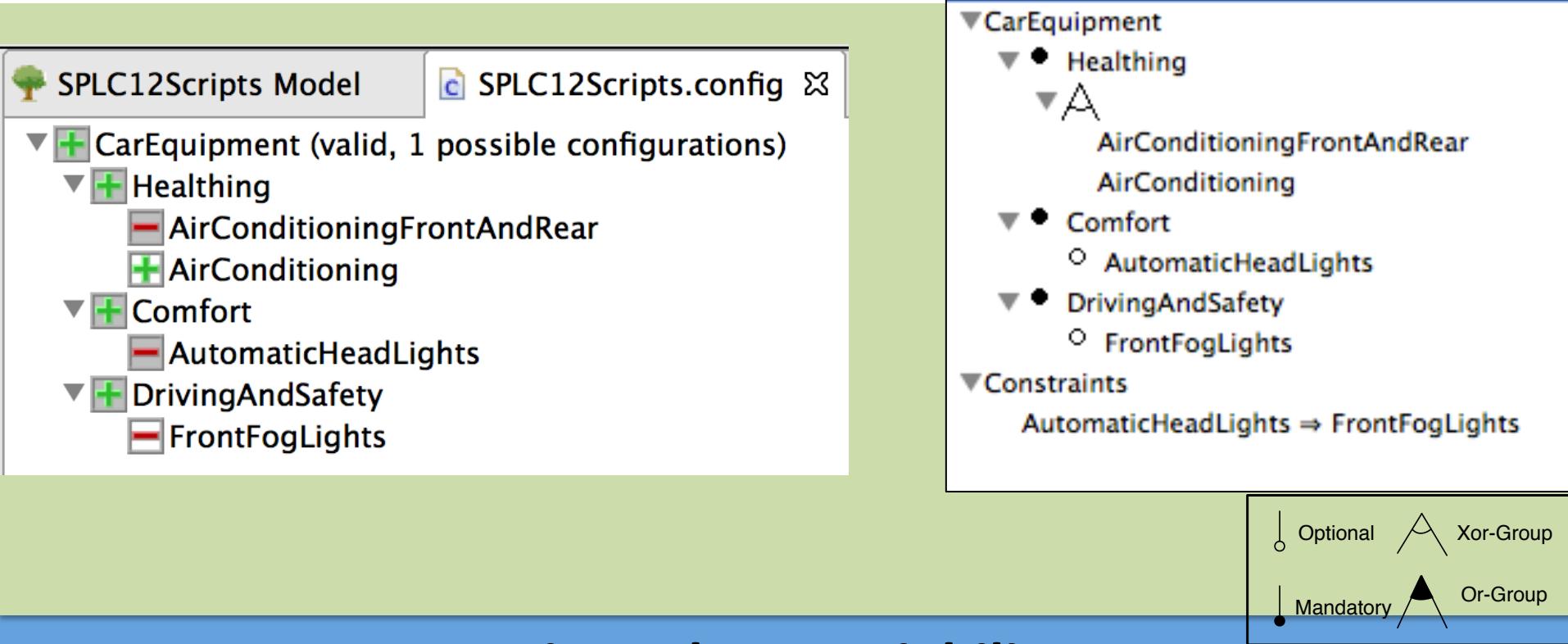
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set of valid configurations

configuration = set of features selected

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





Hierarchy + Variability

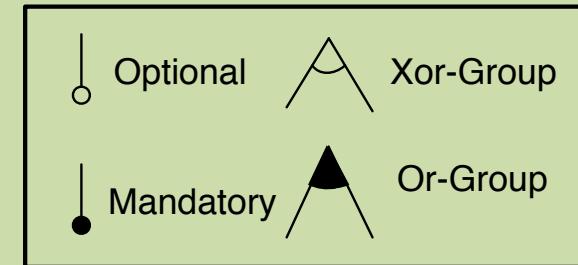
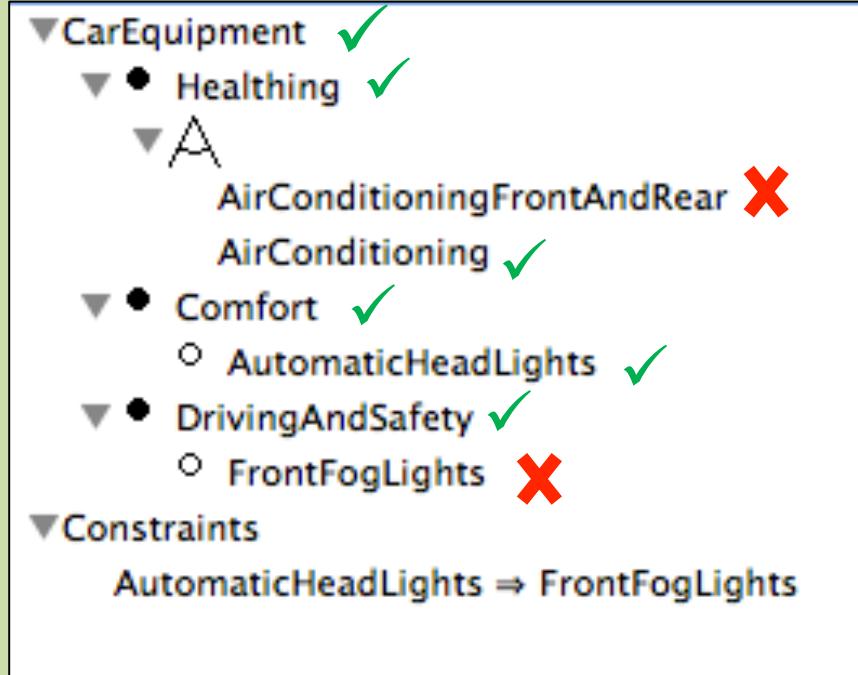
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set of valid configurations

configuration = set of features selected

{CarEquipment, Comfort, DrivingAndSafety, Healthing, AirConditioning}





Hierarchy + Variability

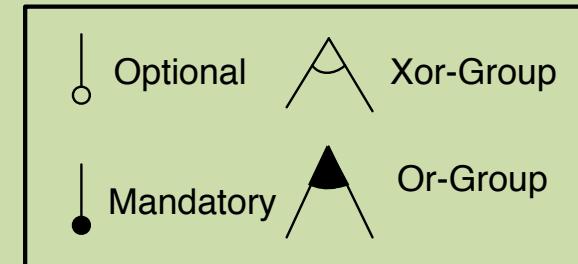
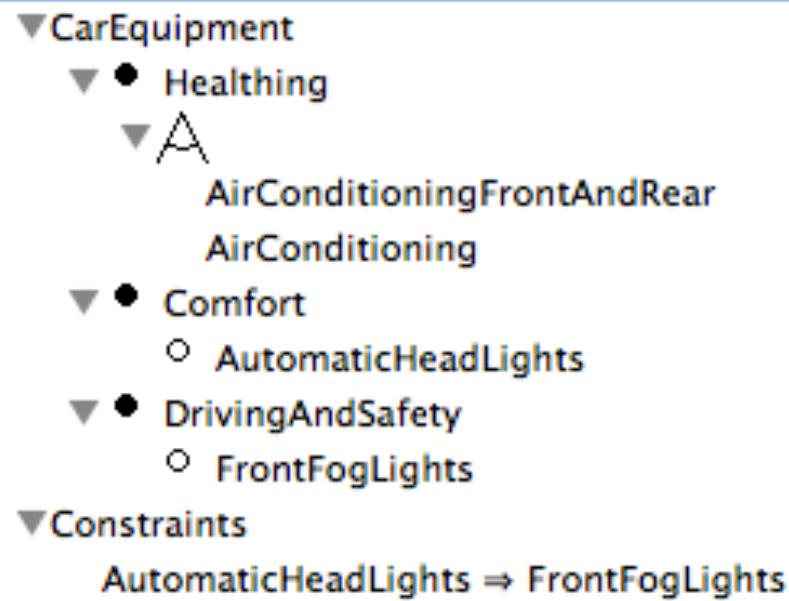
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set of valid configurations

configuration = set of features selected

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





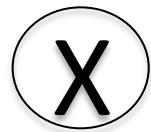
Hierarchy + Variability

=

set of valid configurations

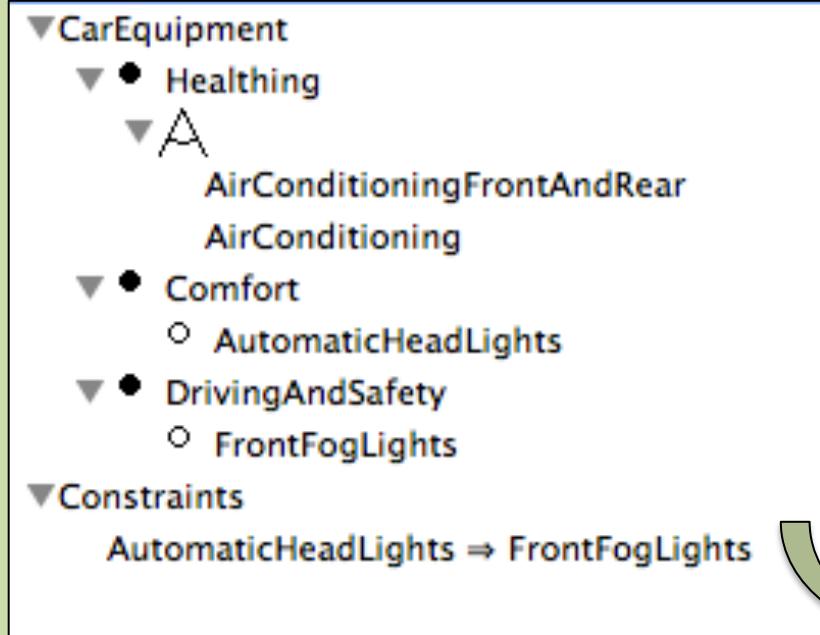
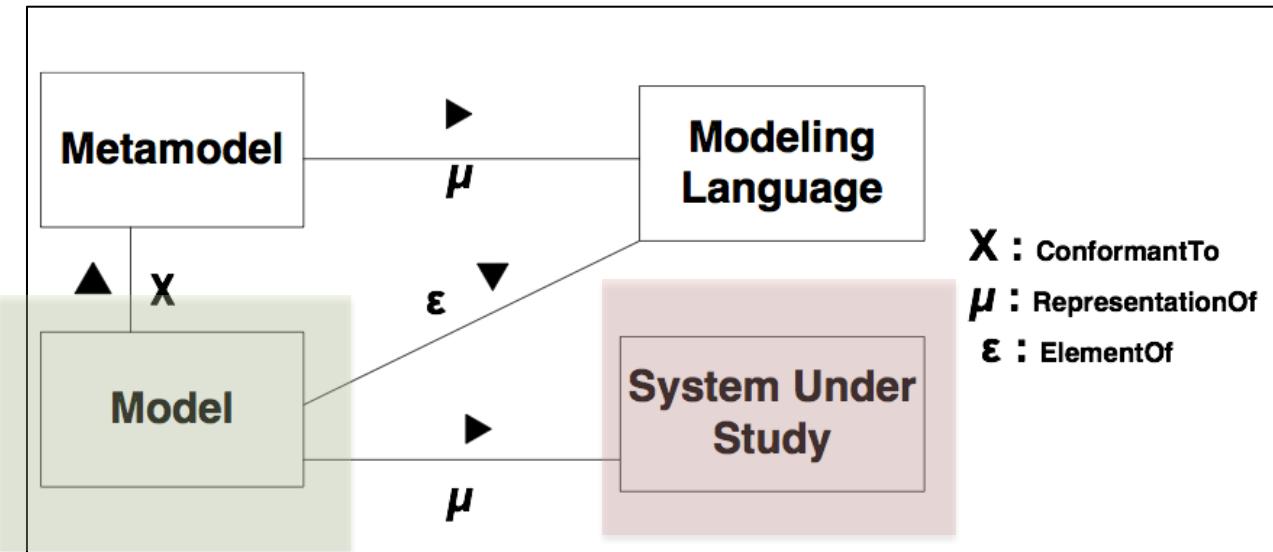


{CarEquipment, Comfort,
DrivingAndSafety,
Healthing}

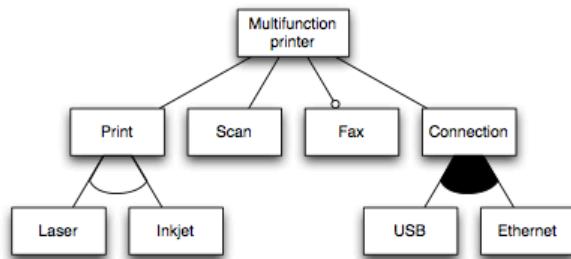


- {AirConditioning, FrontFogLights}
- {AutomaticHeadLights, AirConditioning, FrontFogLights}
- {AutomaticHeadLights, FrontFogLights, AirConditioningFrontAndRear}
- {AirConditioningFrontAndRear}
- {AirConditioning}
- {AirConditioningFrontAndRear, FrontFogLights}

Feature Models



Typical implementations



Fontsource (Attributed - Free Processing 2012) (Attributed - Creative Commons)



result



logics



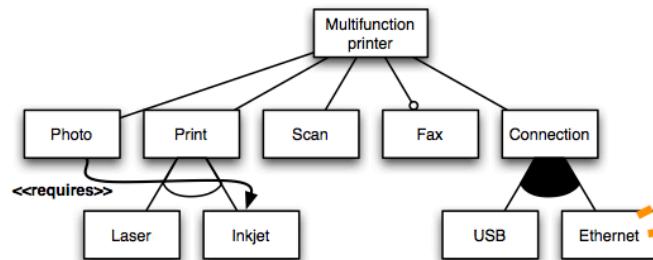
solvers



Z3

Product Derivation

feature model

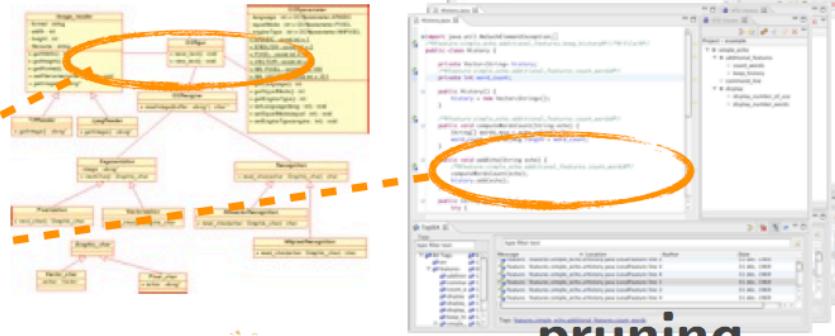


configuration

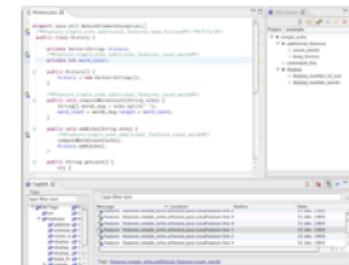
{ MP, Photo, Print, Inkjet, Scan,
Fax, Connection, USB, Ethernet }

product spec

variable model and
code assets



pruning,
composition,
weaving,
transformation



product

Bref
as a product line

ÉTAPE 2 : CHOISIS 3 BONS SOUVENIRS

JE NE VEUX PAS CHOISIR



ÉTAPE 3 : JE REGARDE MON ÉPISODE UNIQUE

DEJÀ 1 796 108 ÉPISODES GENÈRES.



How MDE (IDM) can help

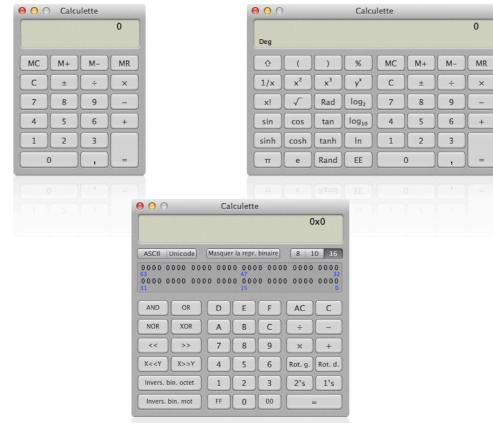
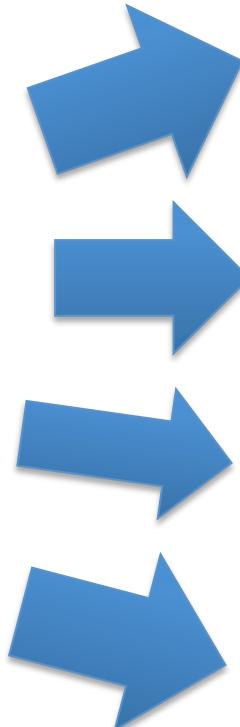
Software Product Line Engineering

Generative approach

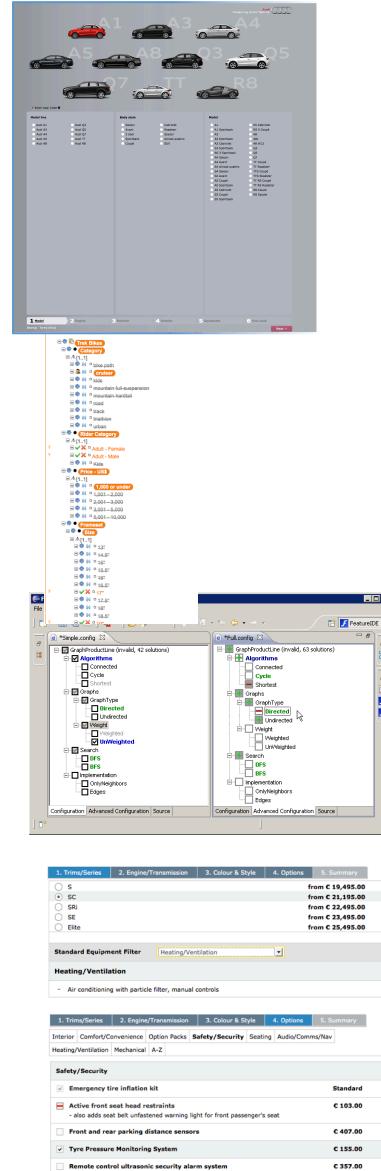
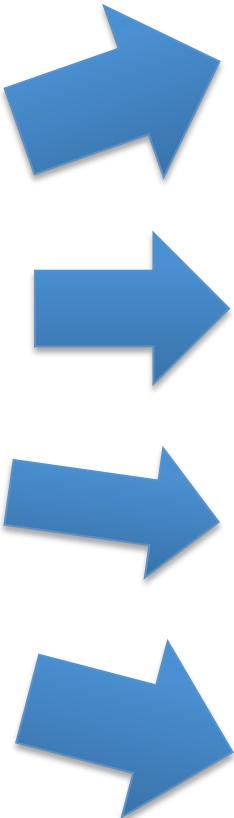
- Programming the generation of programs
 - Very old practice
 - Metaprogramming: generative language and target language are the same
 - Reflection capabilities
- Generalization of this idea:
 - from a specification written in one or more textual or graphical domain-specific languages
 - you generate **customized variants**

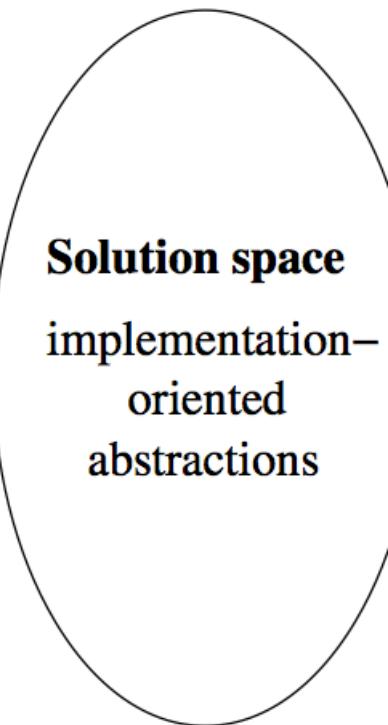
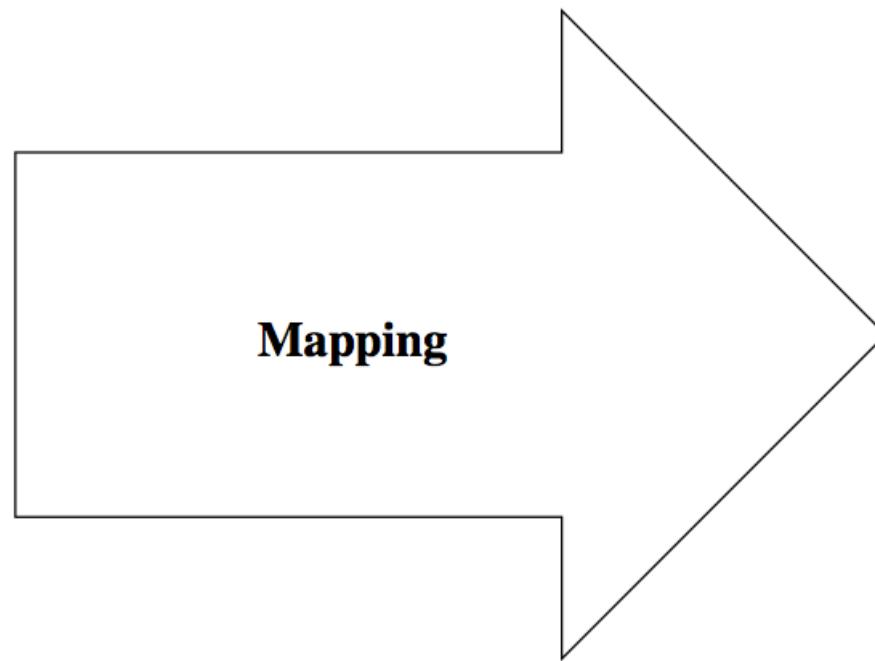
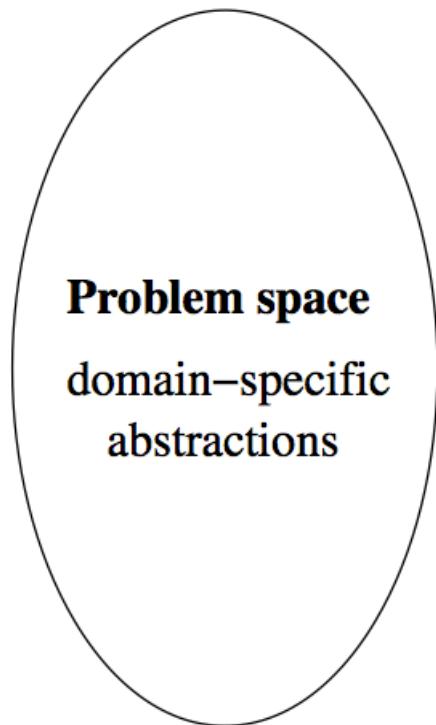
Modeling and implementing system families such that a desired system can be automatically generated from a specification written in one or more textual or graphical domain-specific languages.

Models
And
Languages

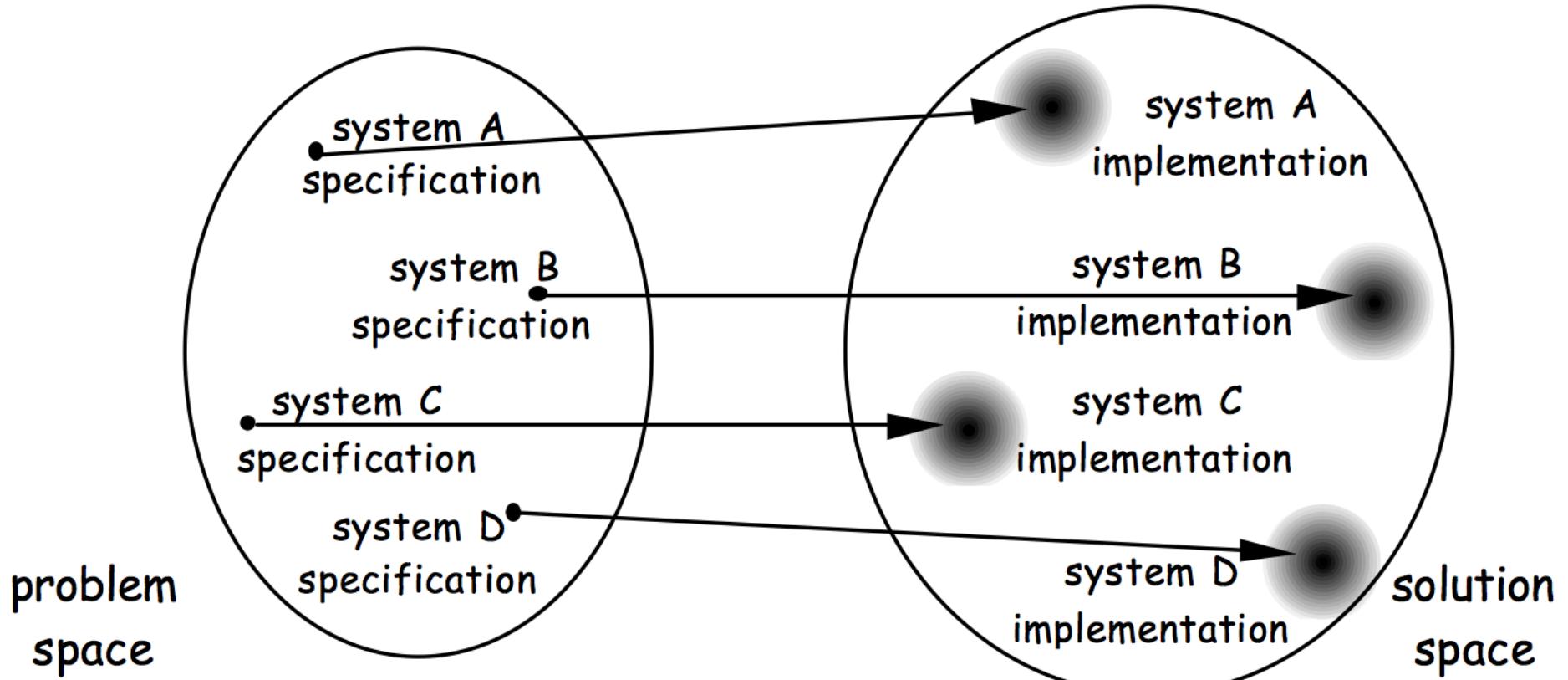


Models And Languages





[Czarnecki and Eisenecker 2000]



[Czarnecki, PhD thesis]

Developing Product Lines

Metamodels, DSLs, and Transformations to the rescue

- Domain Engineering
 - Domain Models
 - Level of abstraction
 - Domain-specific modeling languages
 - (visual or textual) syntax, precise semantics
 - analyzed (verification)
 - Traceability between the artefacts
- Application Engineering
 - Model transformations (automation)
- Reduce the gap

Summary

- **Software product line engineering**
 - Mass customization
 - Family of software intensive systems
 - Systematic reuse
 - Domain engineering
 - Variability management
 - **Variability** everywhere
 - Applied and applicable to many industries and domains
 - **Modeling and implementing variability:** an overview
- 
- 