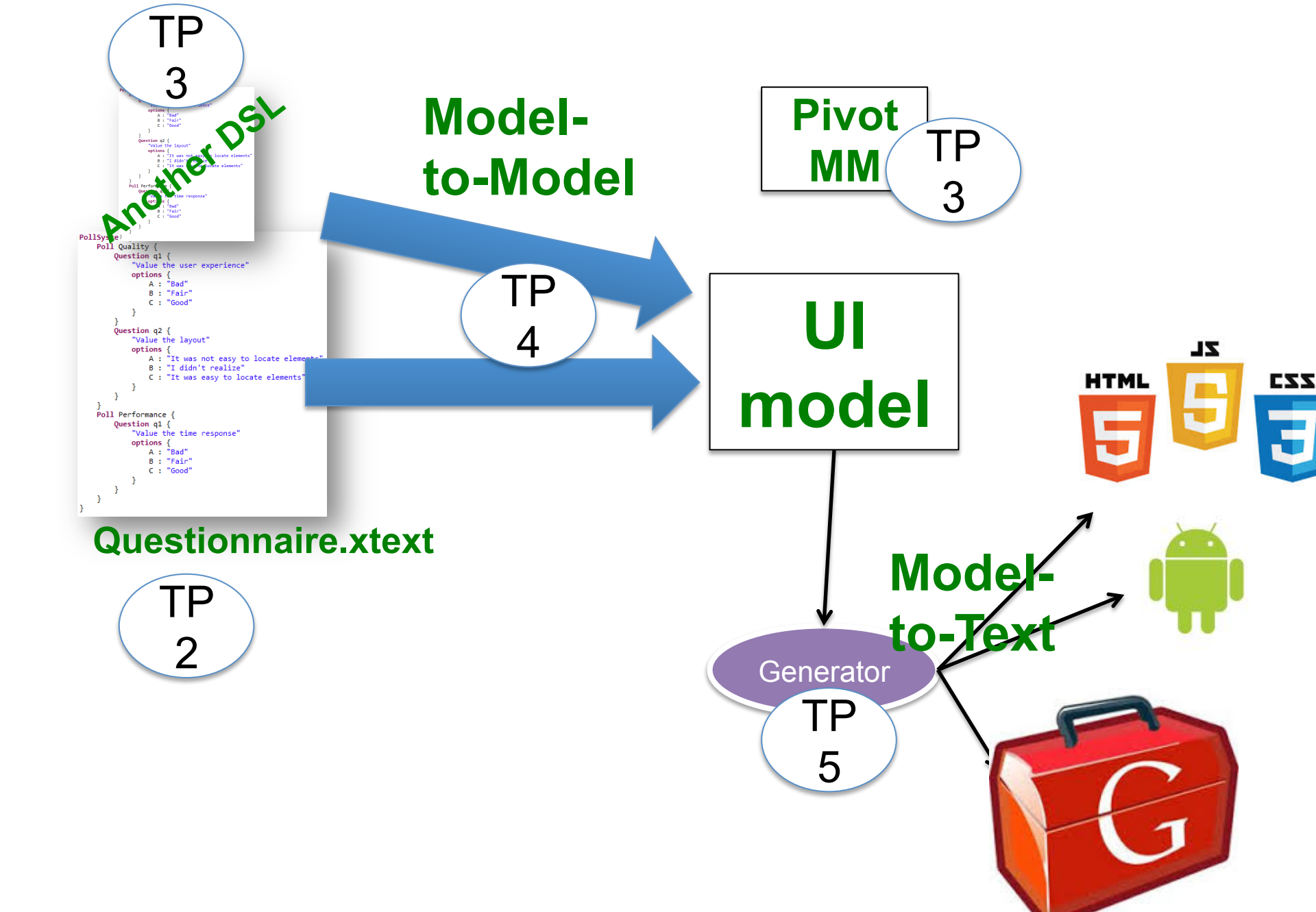
Model-based Software Product Lines

Overview and Principles

Mathieu Acher
Maître de Conférences
mathieu.acher@irisa.fr

Material

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


TP 3
Another DSL
Model-to-Model
Pivot MM
TP 3
TP 4
UI model
Questionnaire.xtext
TP 2
Model-to-Text
Generator
TP 5

Plan

- Challenges and Overview
  - Developping 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

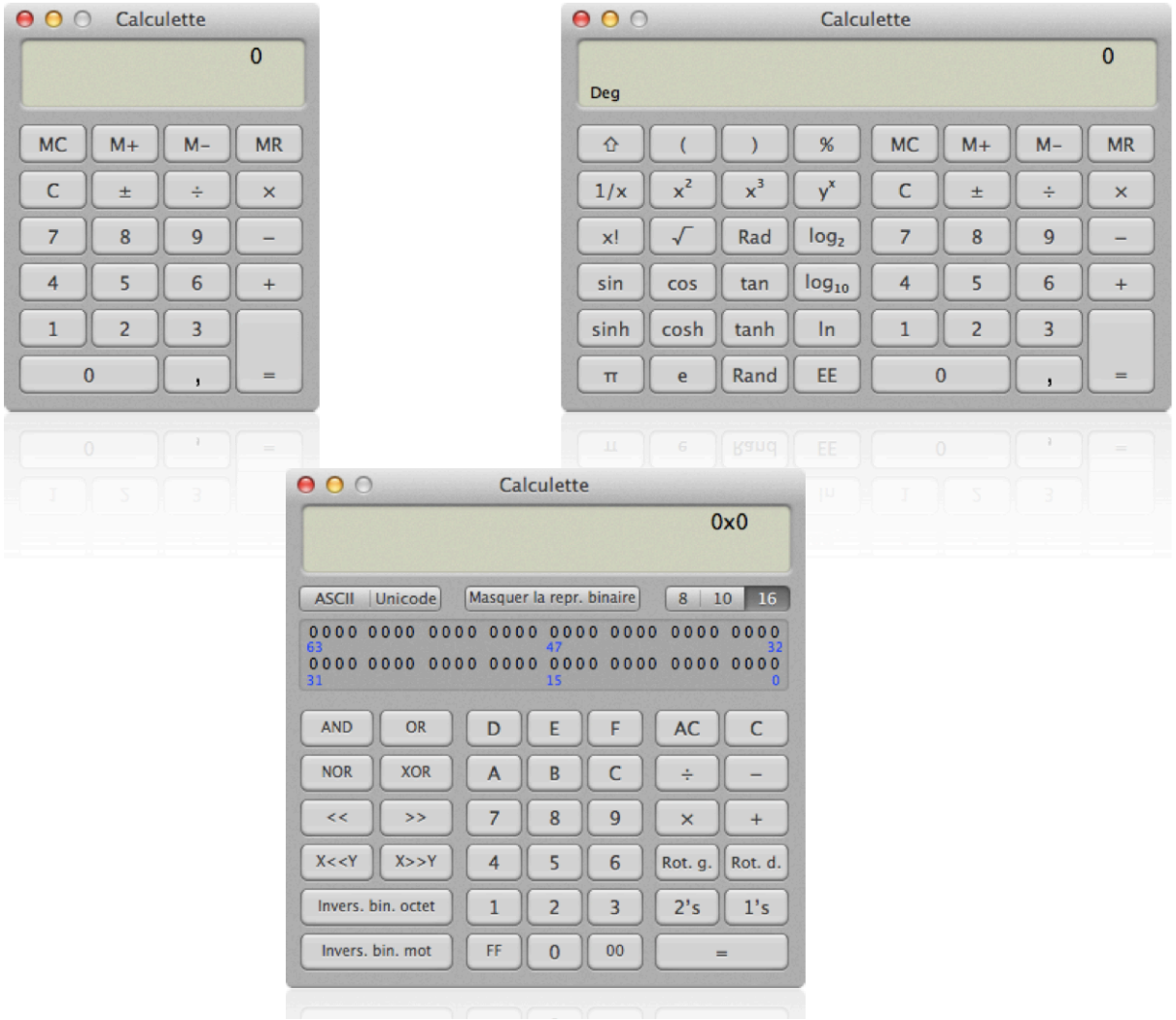
Contract

- 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


Calculette
0
MC M+ M− MR
C ± ÷ ×
7 8 9 −
4 5 6 +
1 2 3 =
0 ,
Calculette
0
Deg
⇧ ( ) % MC M+ M− MR
1/x x² x³ yˣ C ± ÷ ×
x! √ Rad log₂ 7 8 9 −
sin cos tan log₁₀ 4 5 6 +
sinh cosh tanh ln 1 2 3 =
π e Rand EE 0 ,
Calculette
0x0
ASCII Unicode
Masquer la repr. binaire
8 10 16
0000 0000 0000 0000 0000 0000 0000 0000
63 47 32
0000 0000 0000 0000 0000 0000 0000 0000
31 15 0
AND OR D E F AC C
NOR XOR A B C ÷ −
<< >> 7 8 9 × +
X<<Y X>>Y 4 5 6 Rot. g. Rot. d.
Invers. bin. octet 1 2 3 2's 1's
Invers. bin. mot FF 0 00 =

« 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, 1976

Starter

Home Premium Upgrade

$119.99*

Buy

Professional Upgrade

$199.99*

Buy

Ultimate Upgrade

$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		✓	✓	✓

NOKIA
Connecting People

Know our past. Create the future...

1982 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994

1995 1996 1997 1998 1999

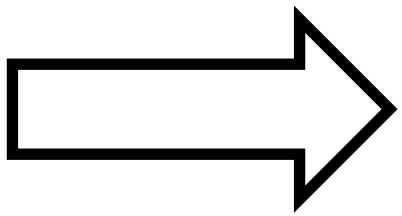
2000 2001 2002

2003 2004

2005

2006 UI

Software-intensive systems

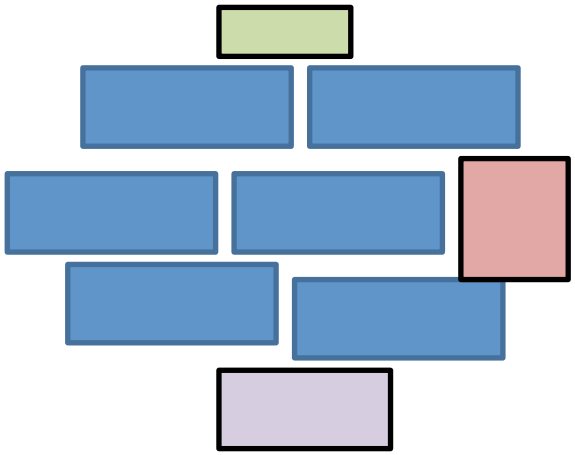


come in many **variants**

Software Product Line Engineering

Factoring out **commonalities**

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



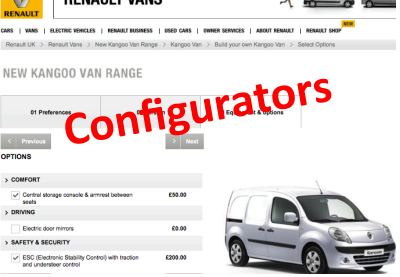
Managing **variabilities**

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

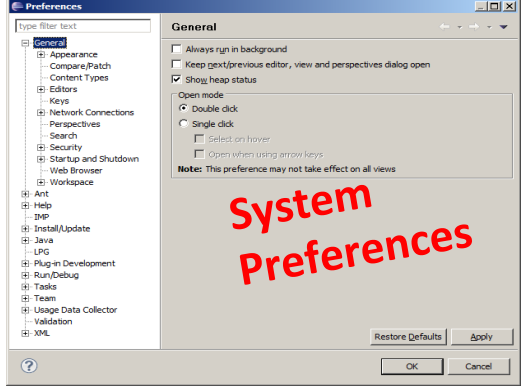
Variability

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

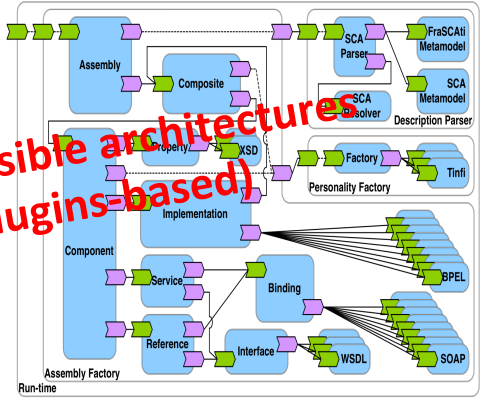
Mikael Svahnberg, Jilles van Gurp, and Jan Bosch (2005)



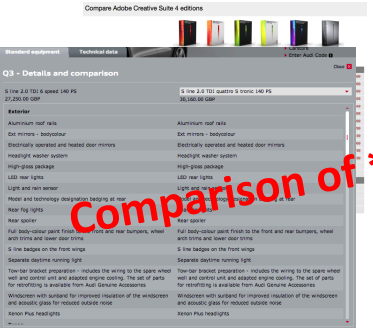
Configurators



System Preferences

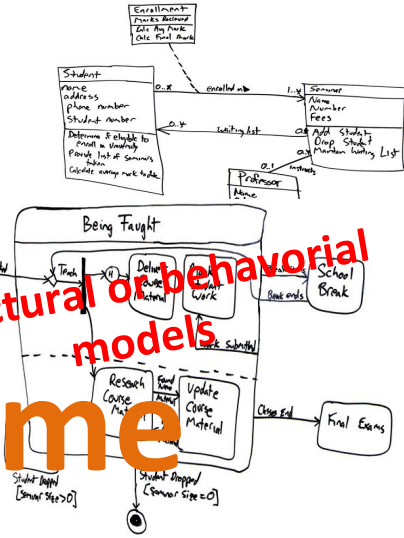


Extensible architectures (eg plugins-based)

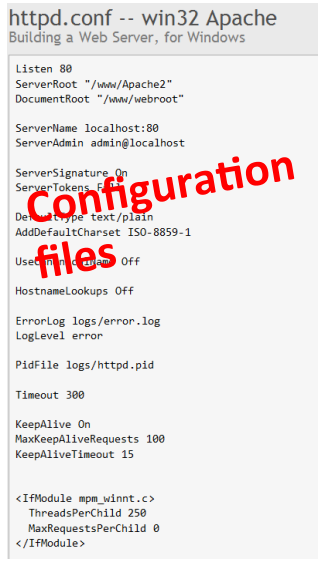


Comparison of *

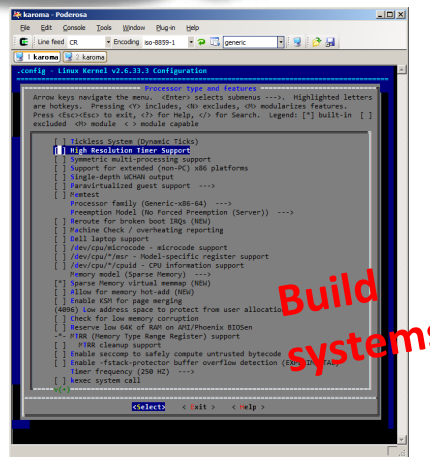
External Variability
Internal Variability
Variability @ run.time



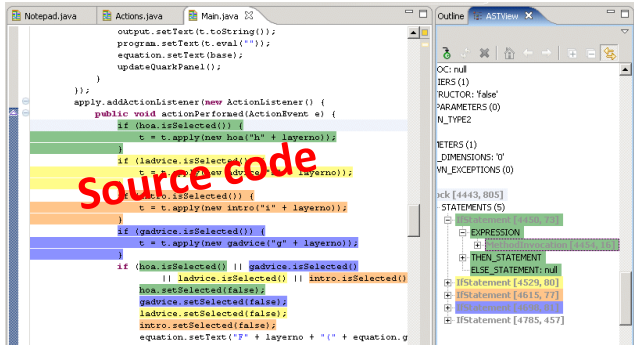
Structural or behavorial models



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
Screensave
Security
Spot t Plug Utilities
System ilities
Video
Word Processing

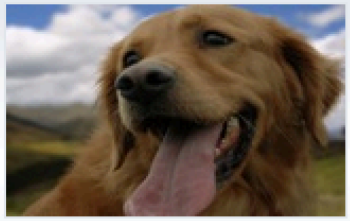
LOBAL PAGES >>
EWS ARCHIVE >>
OFTPEDIA REVIEWS >>
EET THE EDITORS >>

Power Matte 2 1.3 update

Adobe Ar plugin that can extract a ect in an i e

[read

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



Grid 1.1 update

Helps you generate perspective grids

[read more >]

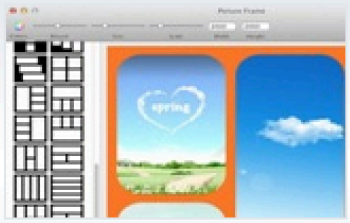
Size:	102 KB
Platform:	Mac OS X 10.8 or later
License:	Commercialware
Rating:	NOT RATED
Downloads:	21
Updated:	June 20th, 07:56 UTC

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 l...
License:	Commercialware
Rating:	Excellent (5.0/5)
Downloads:	297
Updated:	June 20th, 07:53 UTC

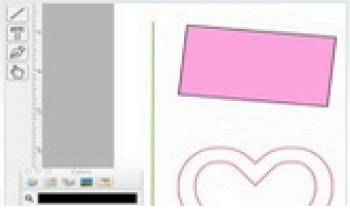


FashionLab Studio 1.1 update

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 l...
License:	Commercialware
Rating:	NOT RATED
Downloads:	3
Updated:	June 20th, 07:49 UTC



Variability

RENAULT

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

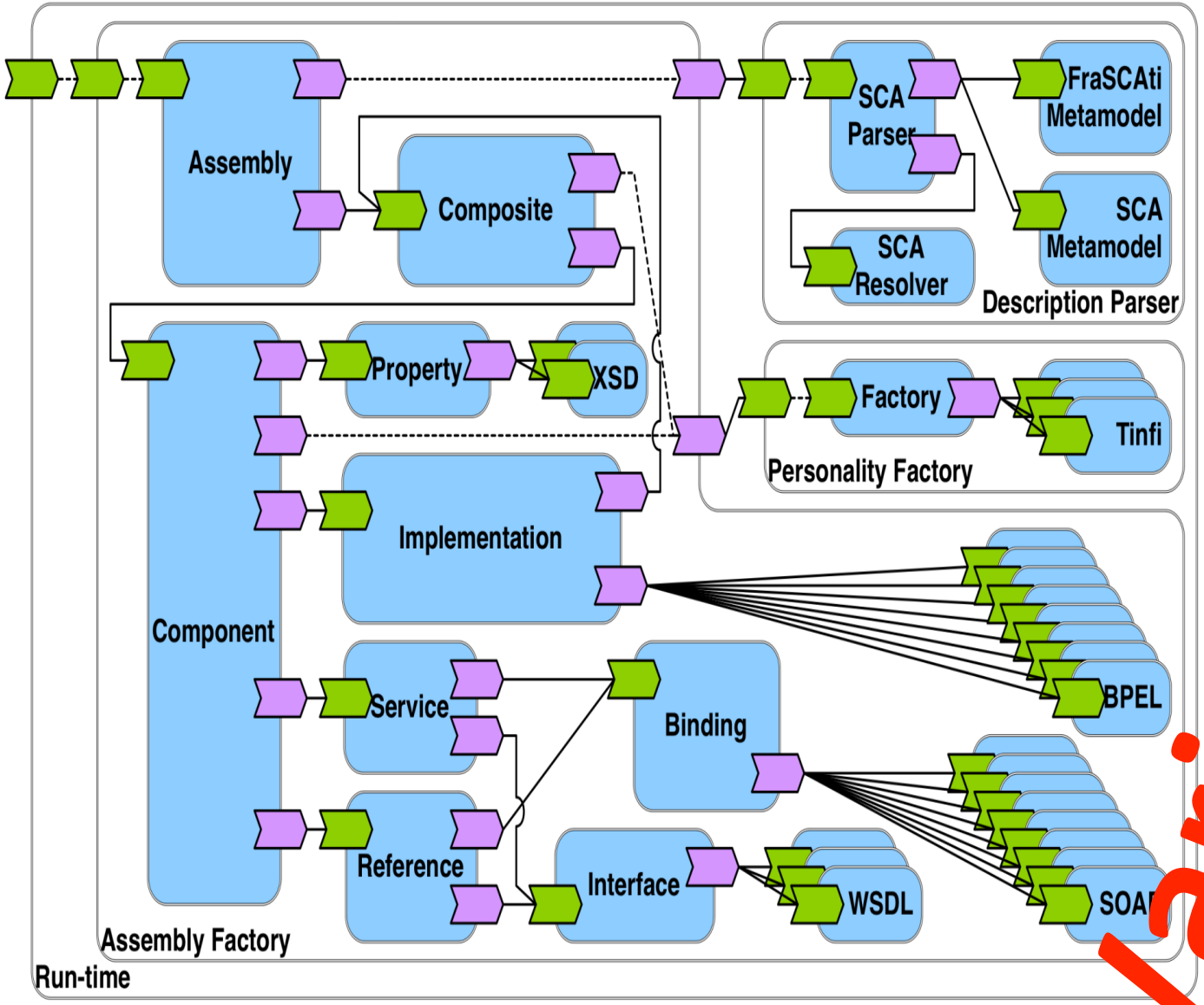
01 Preferences	02 Version	03 Equipment & options

Previous Next

OPTIONS

> COMFORT	
☑ Central storage console & armrest between seats	£50.00
> DRIVING	
☐ Electric door mirrors	£0.00
> SAFETY & SECURITY	
☑ ESC (Electronic Stability Control) with traction and understeer control	£200.00

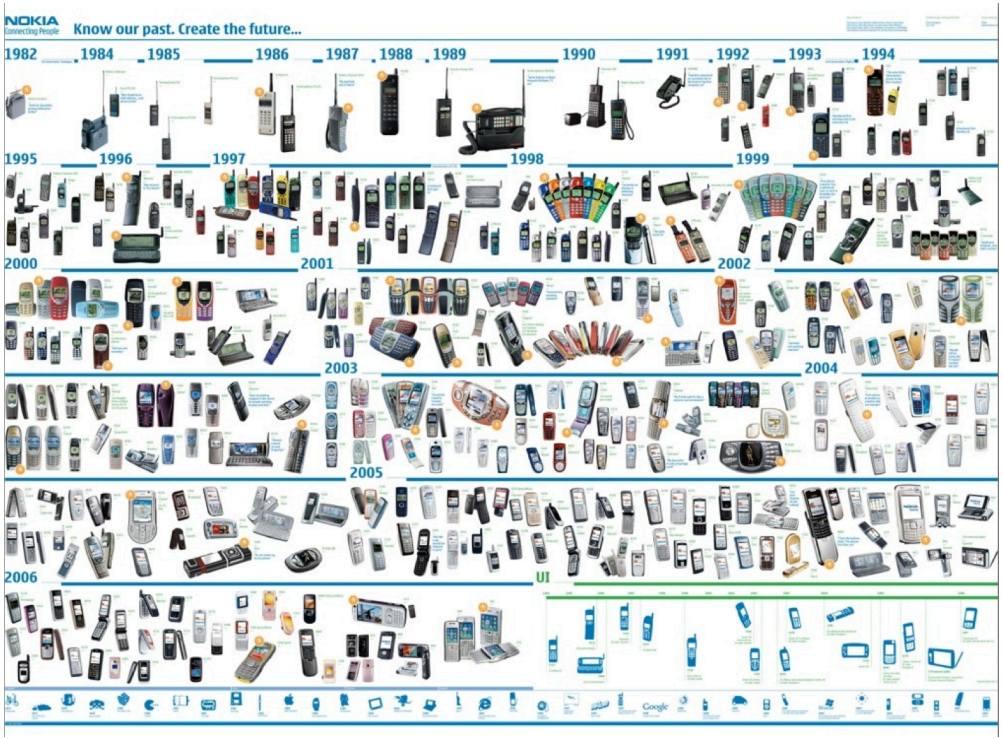
Variability



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**

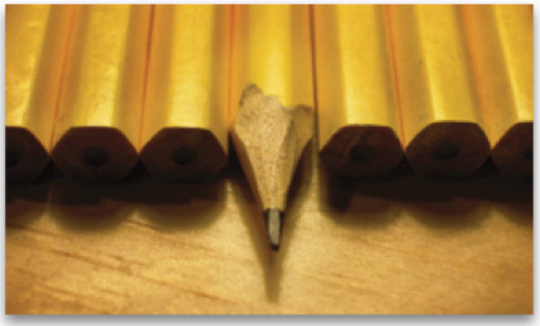


Benefits

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

ERICSSON

NOKIA
Connecting People

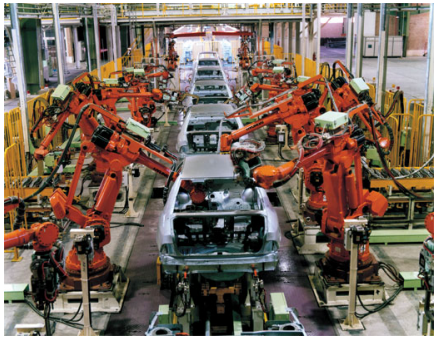
CelsiusTech

Lucent Technologies
Bell Labs Innovations

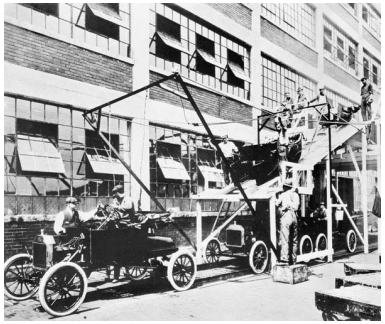
Printer Firmware

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

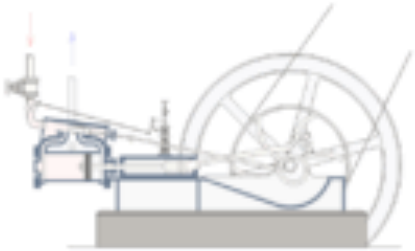
A Bit of History: Industrial Revolution



1980s



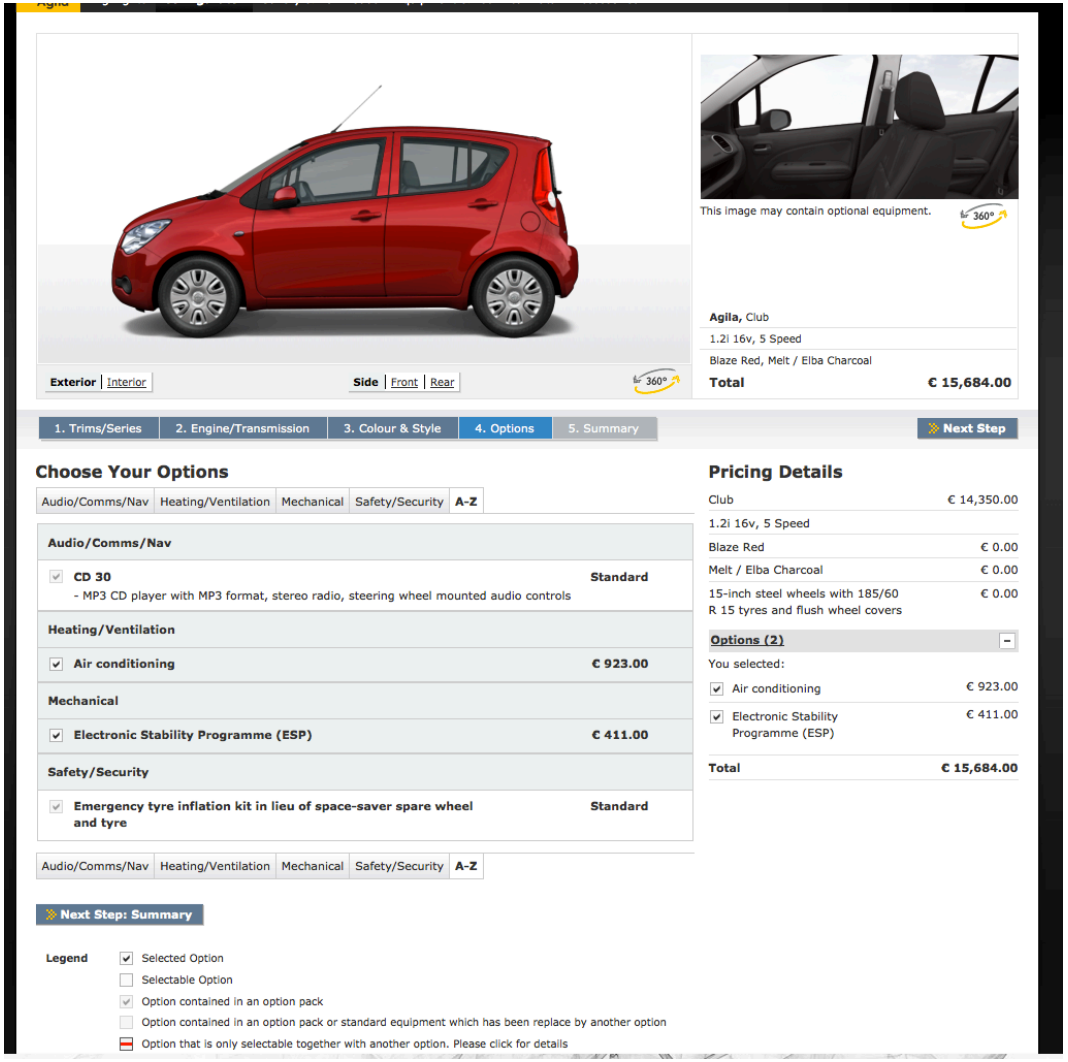
1901
Henry Ford



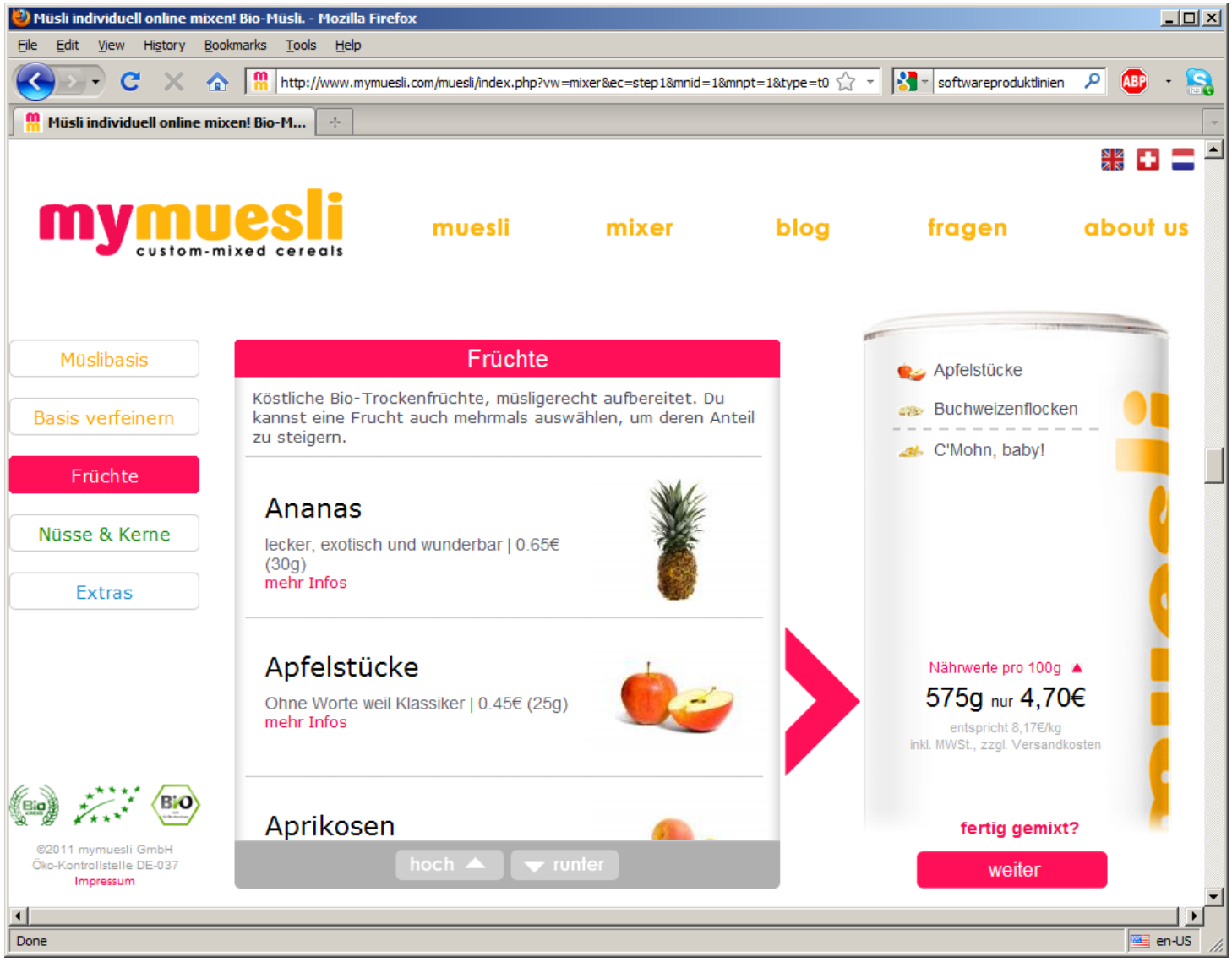
1698
Thomas Savery

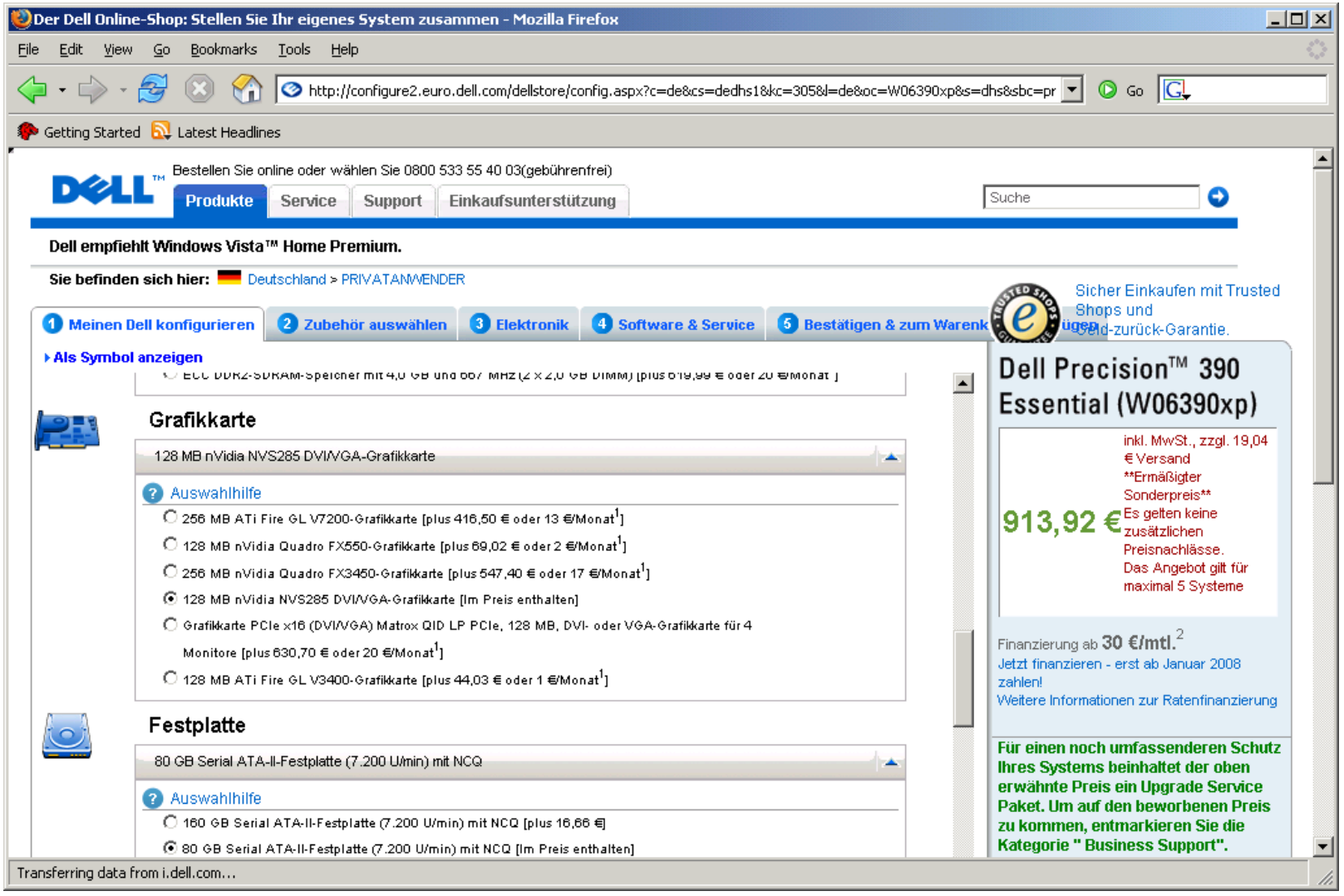
Nowaday: Product Lines Everywhere

Product Lines of Cars

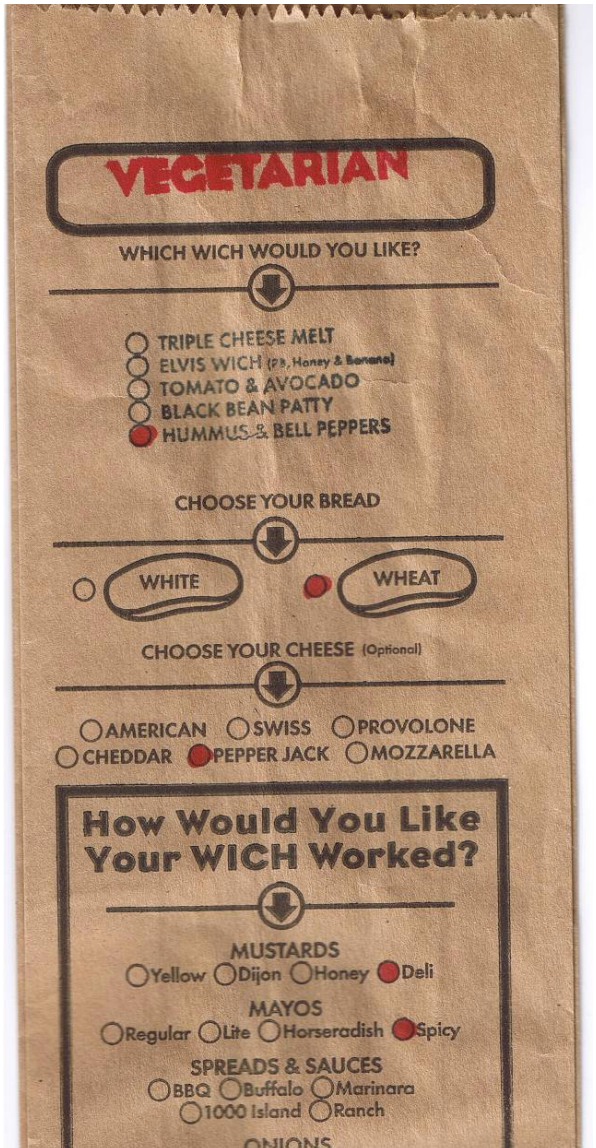



Willkommen bei selve - the shoe individualizer
http://www.selve.net/index_js.html
KOLLEKTION
FUSSTYP
MYSELVE
INFO
HOME
MODELLE
LOOKBOOK
SELVE ID
PASSWORT
>>ANMELDEN
selve
selve Kollektion -> Style: casuals -> Modell: Opal
modell-details
>>hier clicken
>>SELVE SCHUHREGAL
inhalt: 0
>>SHOPPING BAG
inhalt : 0
A. Erstes Oberleder
Velours leder Sand
Velours leder Bordeaux
Velours leder Cognac
Velours leder Sand
B.
C. Futterleder
Beige
D. Absatz
Hufeisen Braun
E. Sohle
Gummisohle
>>ÄNDERN
>>ZURÜCKLEGEN


Müsli individuell online mixen! Bio-Müsli. - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://www.mymuesli.com/muesli/index.php?vw=mixer&ec=step1&mnid=1&mnpt=1&type=t0
softwareproduktlinien
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
©2011 mymuesli GmbH
Öko-Kontrollstelle DE-037
Impressum
Done
en-US


Der Dell Online-Shop: Stellen Sie Ihr eigenes System zusammen - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
http://configure2.euro.dell.com/dellstore/config.aspx?c=de&cs=dedhs1&kc=305&l=de&oc=W06390xp&s=dhs&sbc=pr
Go
Getting Started
Latest Headlines
Bestellen Sie online oder wählen Sie 0800 533 55 40 03(gebührenfrei)
Produkte
Service
Support
Einkaufsunterstützung
Suche
Dell empfiehlt Windows Vista™ Home Premium.
Sie befinden sich hier: Deutschland > PRIVATANWENDER
1 Meinen Dell konfigurieren
2 Zubehör auswählen
3 Elektronik
4 Software & Service
5 Bestätigen & zum Warenk
Sicher Einkaufen mit Trusted Shops und Geld-zurück-Garantie.
Als Symbol anzeigen
Grafikkarte
128 MB nVidia NVS285 DVI/VGA-Grafikkarte
Auswahlhilfe
256 MB ATi Fire GL V7200-Grafikkarte [plus 416,50 € oder 13 €/Monat1]
128 MB nVidia Quadro FX550-Grafikkarte [plus 69,02 € oder 2 €/Monat1]
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 €]
80 GB Serial ATA-II-Festplatte (7.200 U/min) mit NCQ [Im Preis enthalten]
Dell Precision™ 390 Essential (W06390xp)
913,92 €
inkl. MwSt., zzgl. 19,04 € Versand
Ermäßigter Sonderpreis
Es gelten keine zusätzlichen Preisnachlässe.
Das Angebot gilt für maximal 5 Systeme
Finanzierung ab 30 €/mtl.2
Jetzt finanzieren - erst ab Januar 2008 zahlen!
Weitere Informationen zur Ratenfinanzierung
Für einen noch umfassenderen Schutz Ihres Systems beinhaltet der oben erwähnte Preis ein Upgrade Service Paket. Um auf den beworbenen Preis zu kommen, entmarkieren Sie die Kategorie " Business Support".
Transferring data from i.dell.com...

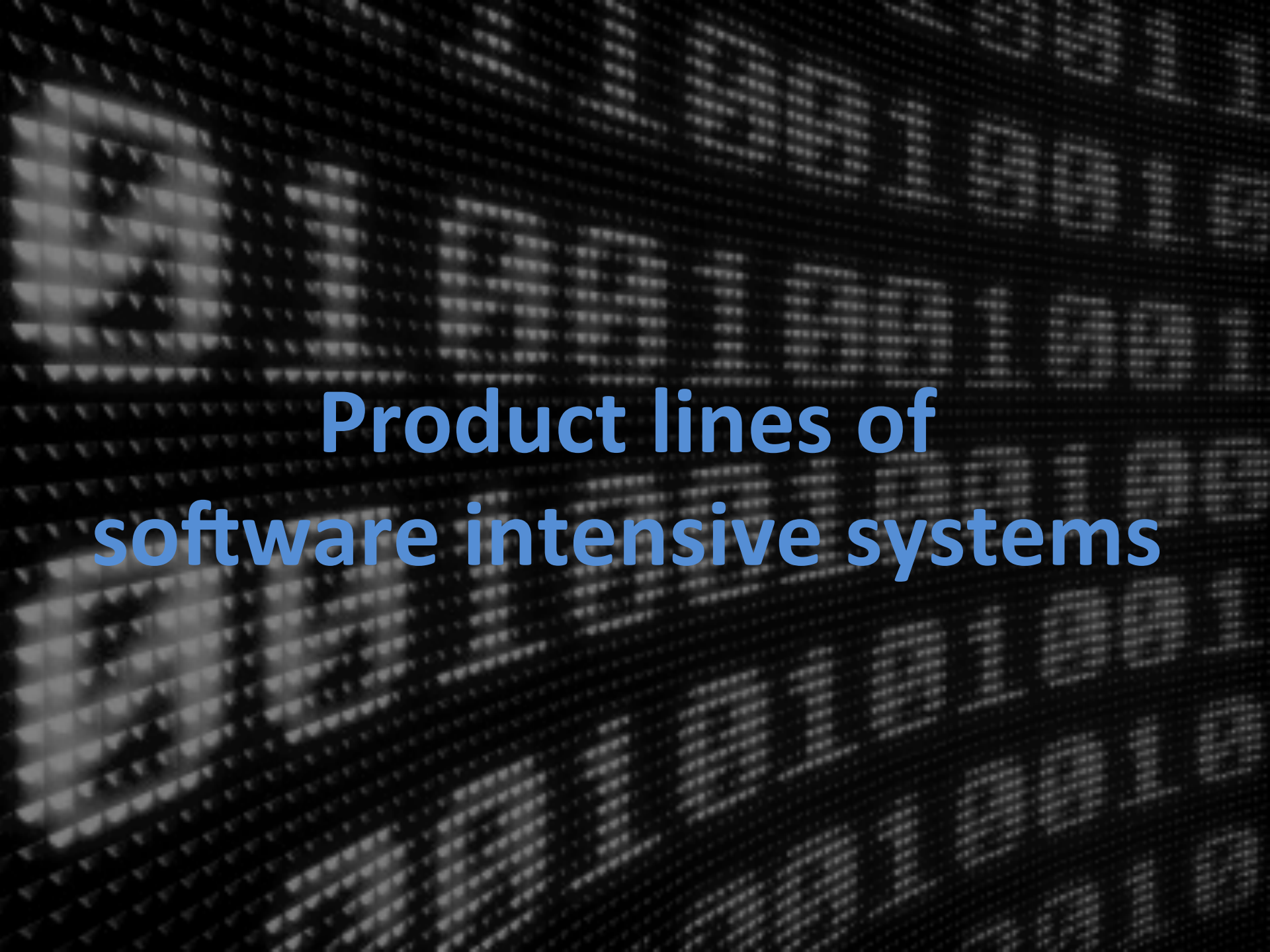
Food? Product lines!




VEGETARIAN
How Would You Like Your WICH Worked?
VEGETARIAN
How Would You Like Your WICH Worked?

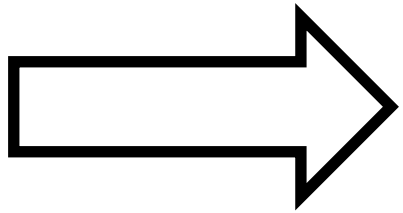
Mass production

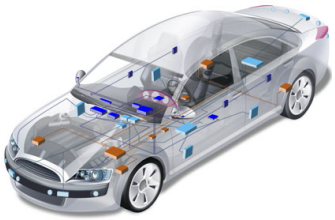

What about
software?


Product lines of
software intensive systems

Software intensive systems

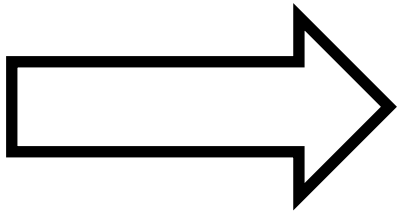
are declined in many **variants**





Software intensive systems

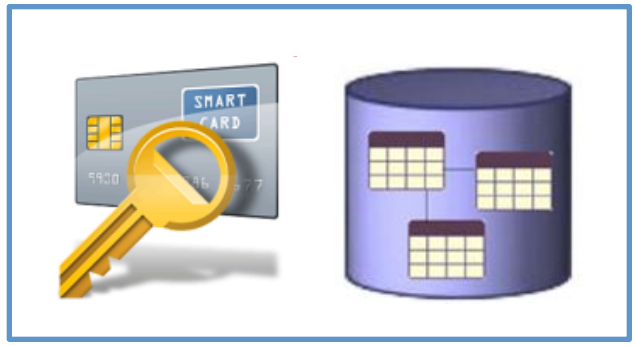
are declined in many **variants**



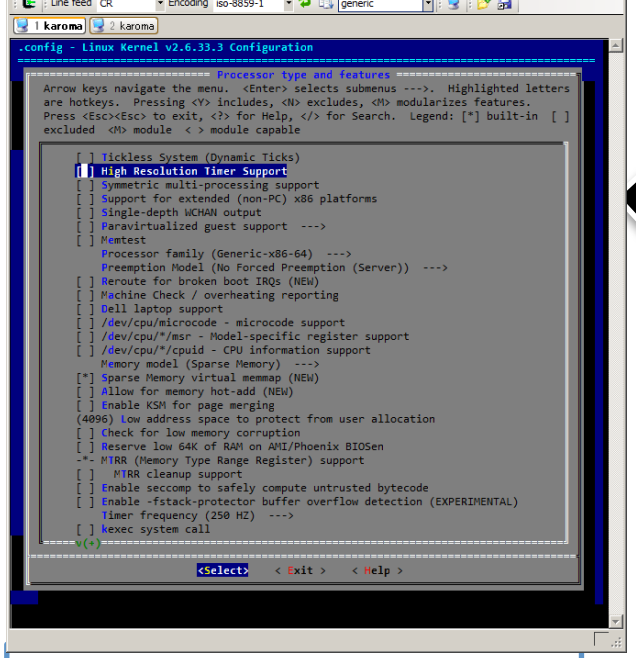
Software Product Lines

Car

Database Engine

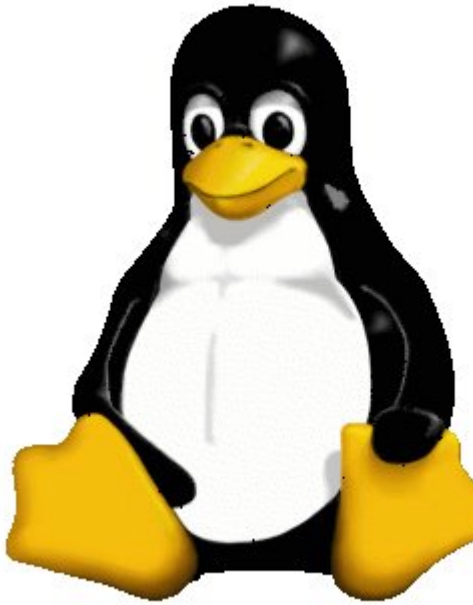


Printer Firmware

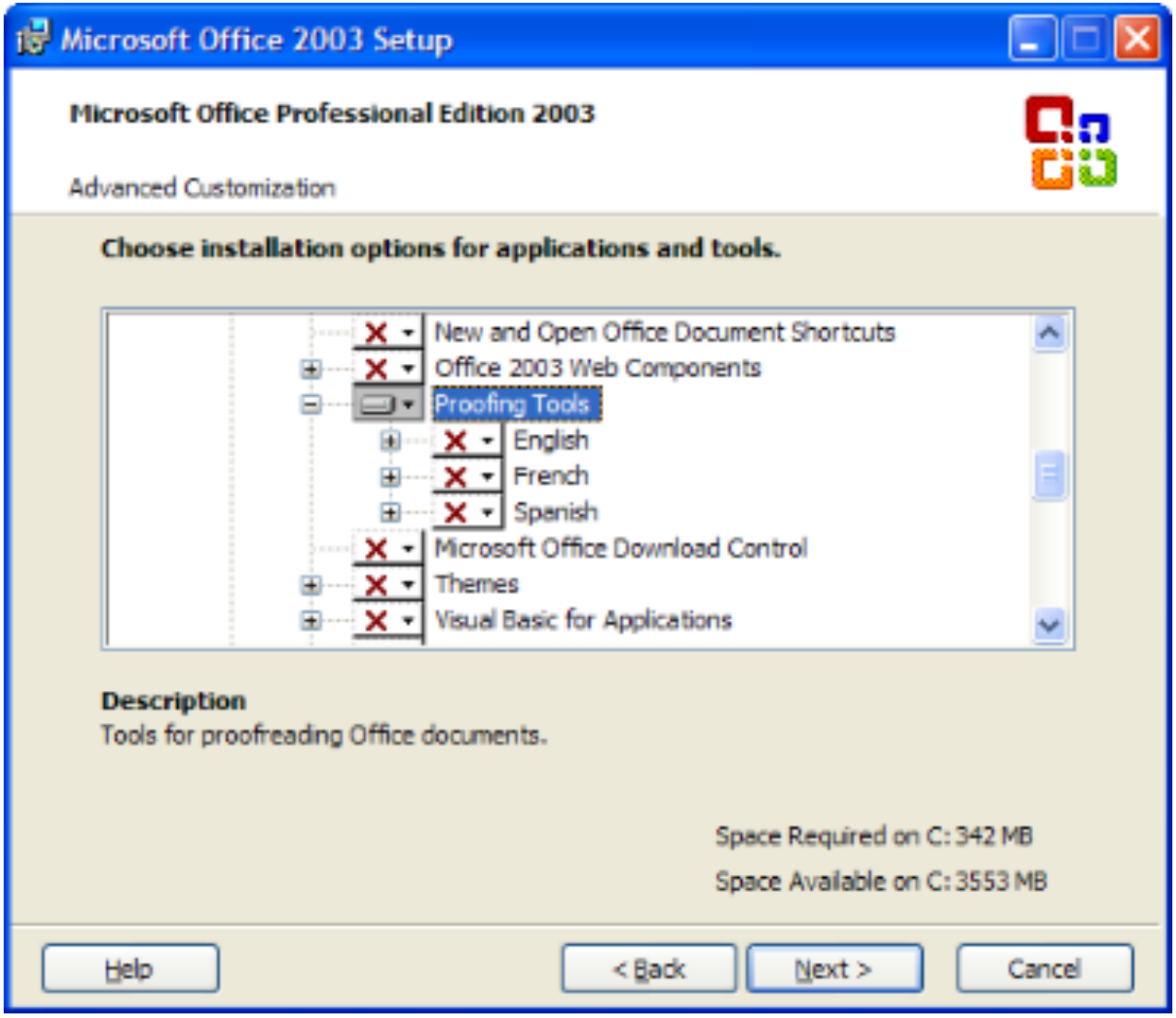


Linux Kernel

Linux-Kernel



Features in Microsoft Office



Bref

bref30ans.canalplus.fr

CANAL+ 30ANS

BREF | PROGRAMMES | SURPRISES | EXPO

bref.
CANAL a 30 ans.

ETAPE 1 : DONNE TON PRENOM

MATHIEU → OK

Online Generator

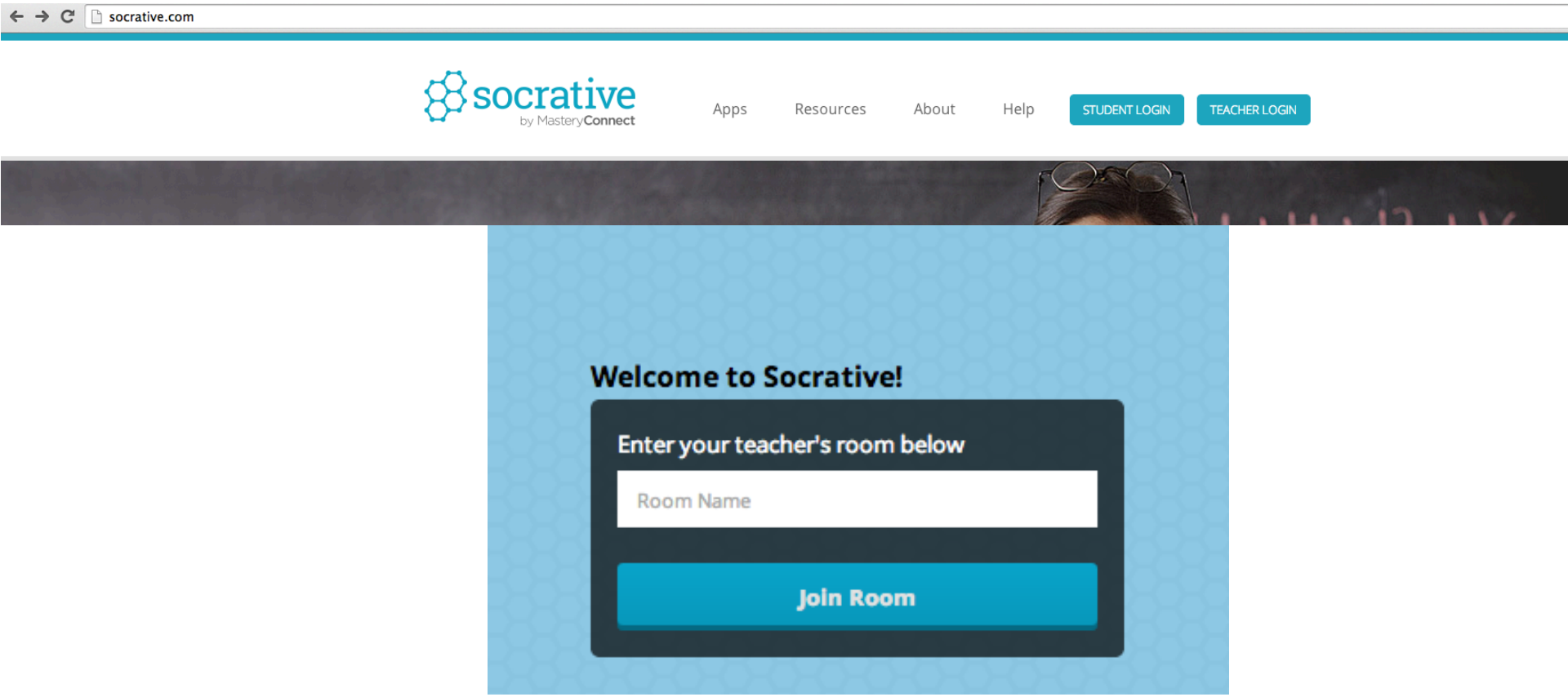
bref30ans.canalplus.fr/#c

ETAPE 2 : CHOISIS 3 BONS SOUVENIRS

Variant


bref30ans.canalplus.fr/#video
ETAPE 3 : JE REGARDE MON EPISODE UNIQUE
DEJÀ 761 545 EPISODES GENERES.
MATHIEU+
présente
HD
POWERED BY MICROSOFT AZURE

Quizz Time



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"

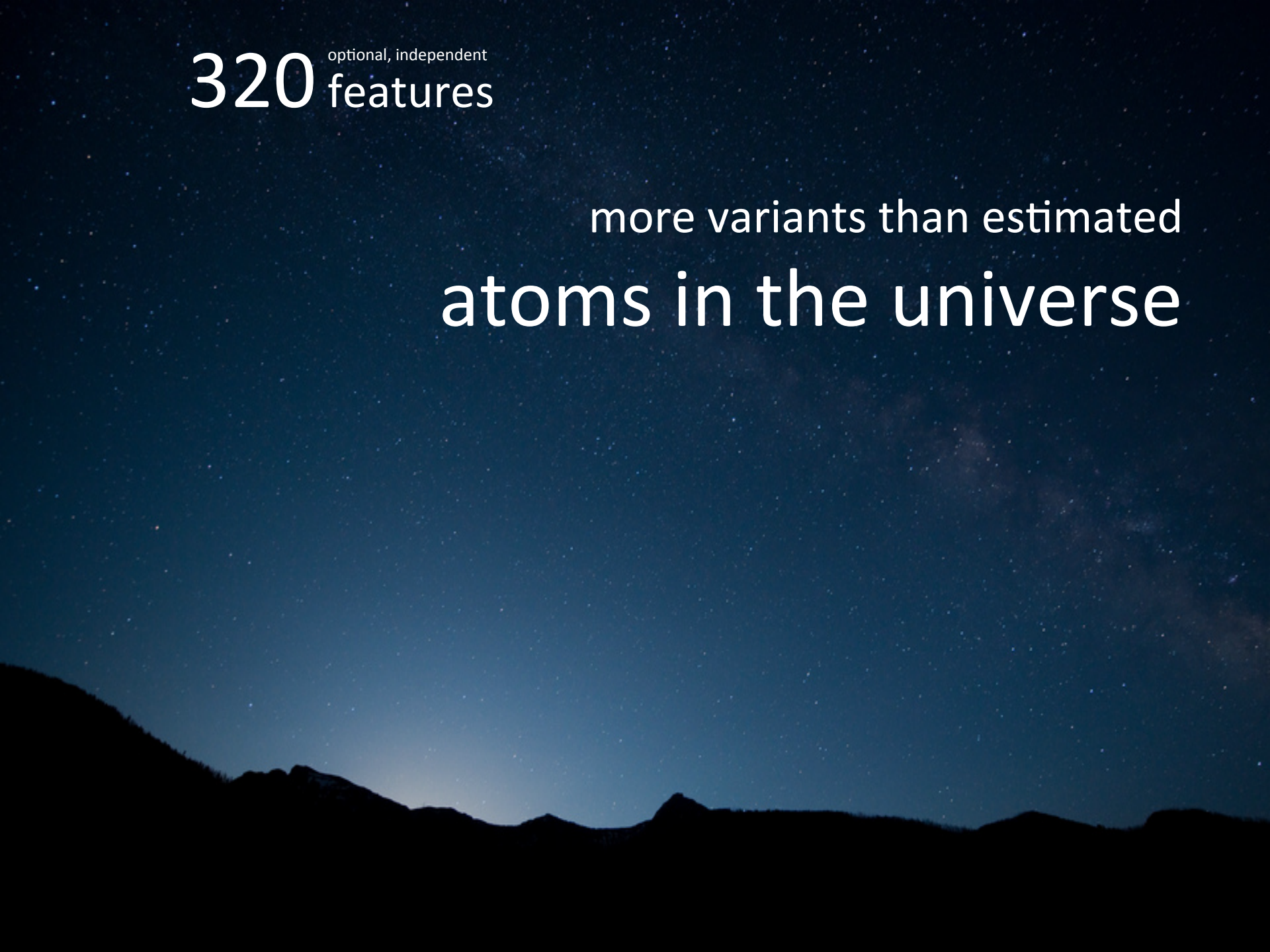
Mikael Svahnberg, Jilles van Gurp, and Jan Bosch (2005)


Variability = Complexity

33 optional, independent features

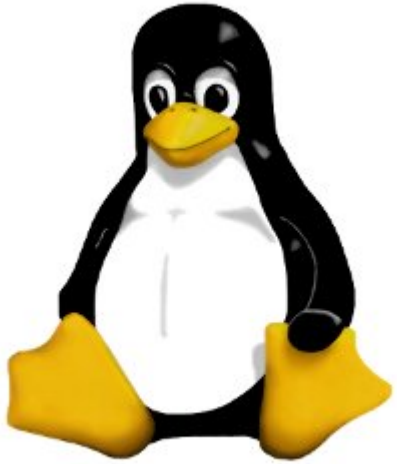
a unique variant for every

person on this planet

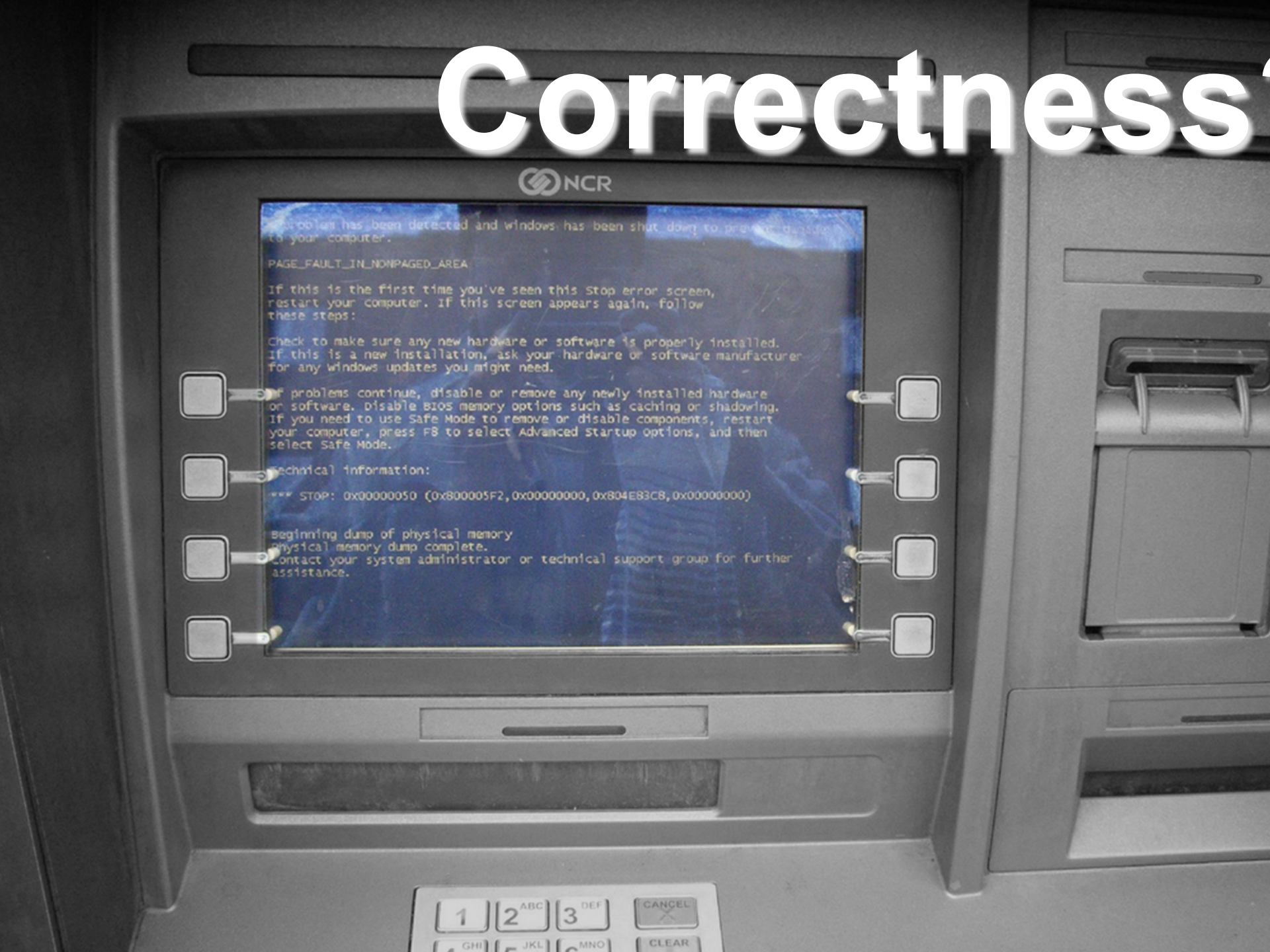

320 optional, independent features
more variants than estimated
atoms in the universe

2000 features

10000 features




Automation?
Avoid solving the same problem!
2, 3…n times


Correctness
NCR
PAGE_FAULT_IN_NONPAGED_AREA
If this is the first time you've seen this Stop error screen,
restart your computer. If this screen appears again, follow
these steps:
Check to make sure any new hardware or software is properly installed.
If this is a new installation, ask your hardware or software manufacturer
for any windows updates you might need.
If problems continue, disable or remove any newly installed hardware
or software. Disable BIOS memory options such as caching or shadowing.
If you need to use Safe Mode to remove or disable components, restart
your computer, press F8 to select Advanced Startup Options, and then
select Safe Mode.
Technical information:
*** STOP: 0x00000050 (0x800005F2,0x00000000,0x804E83C8,0x00000000)
Beginning dump of physical memory
Physical memory dump complete.
Contact your system administrator or technical support group for further
assistance.
1
2 ABC
3 DEF
CANCEL
CLEAR

Maintenance?
Comprehension?

Checking **Products**

2000 Features
100 Printers
30 New Printers per Year

Printer Firmware

Checking **Products**

8000 Features

? Products

Linux Kernel

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

Customization

Automation

Commonality

Variability

Assembly Line and Mass Customization

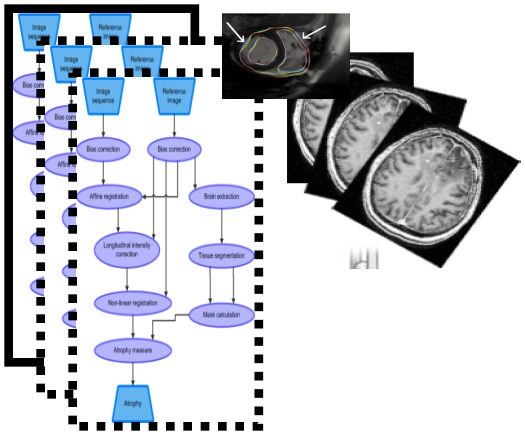
Reuse and Mass Customization

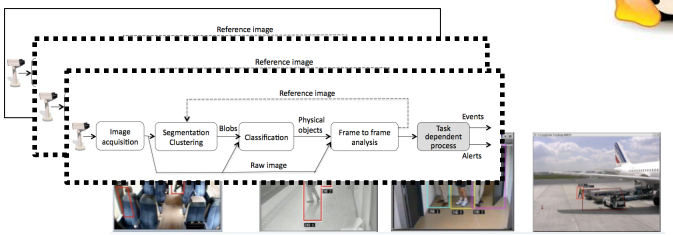

Starting from scratch?


You cannot start from scratch

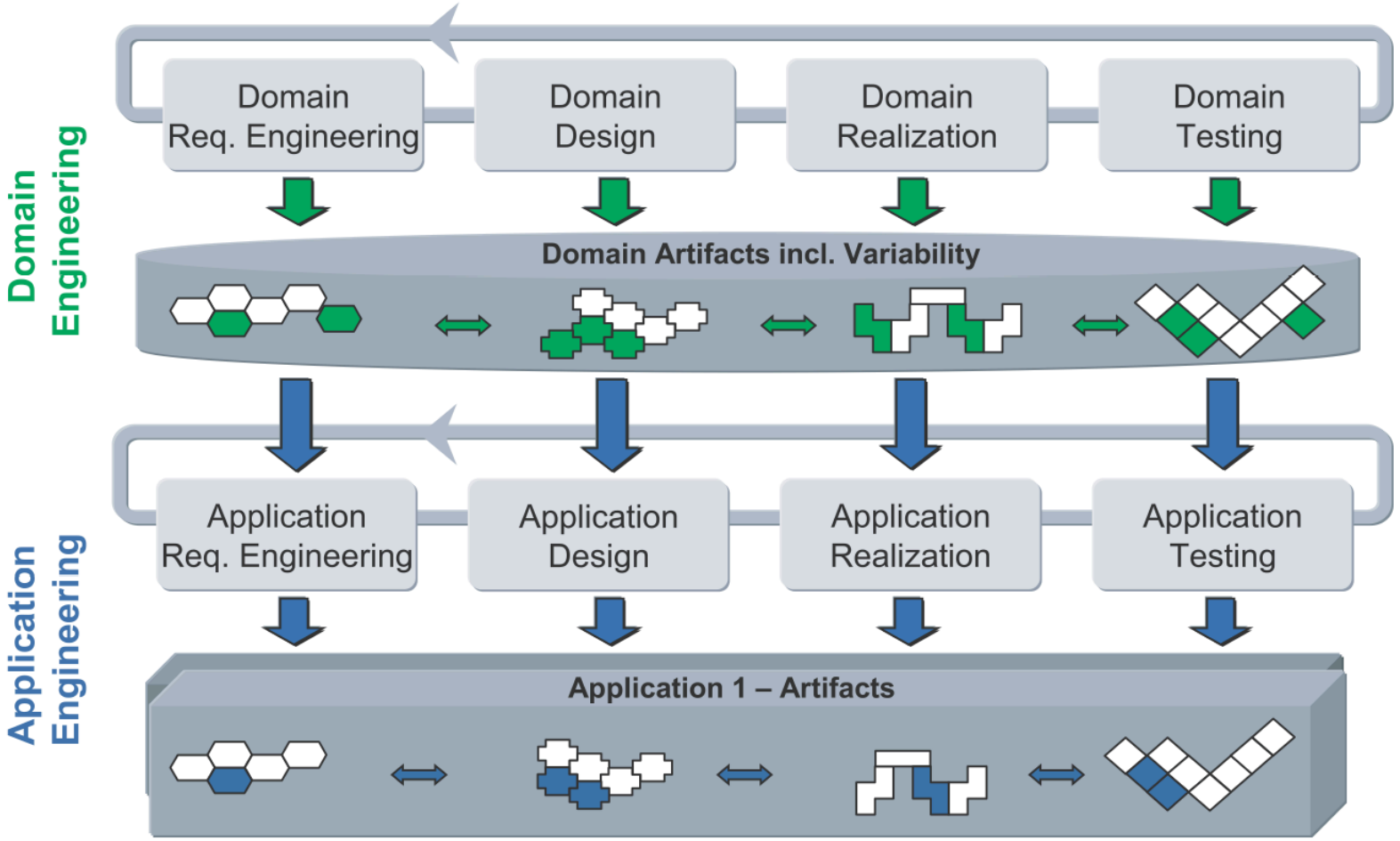
"a set of software- intensive systems that share a common, managed set of features satisfying the specific needs of a particular market segment or mission and that are developed from a common set of core assets in a prescribed way" **[Clements et al., 2001]**

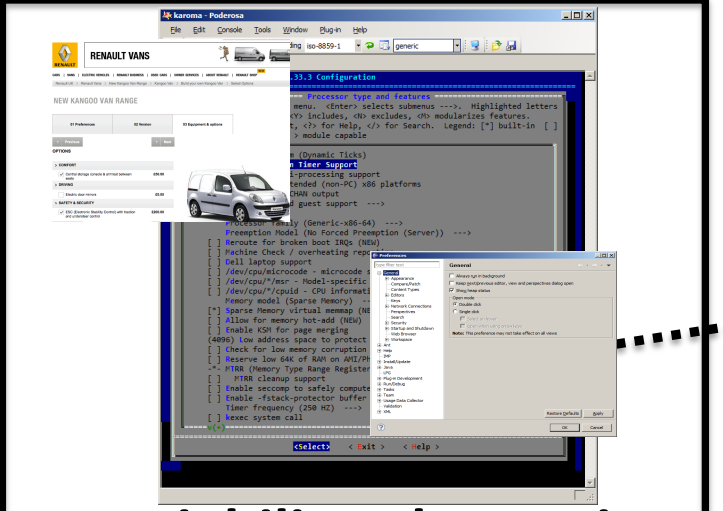
Software Product Lines





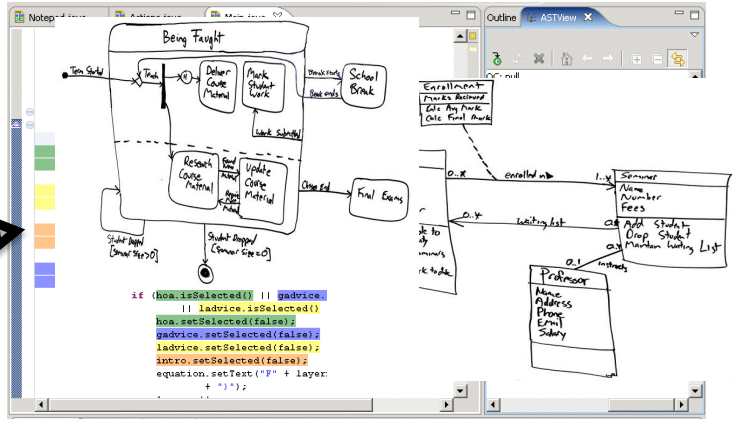
Software Product-Line Engineering



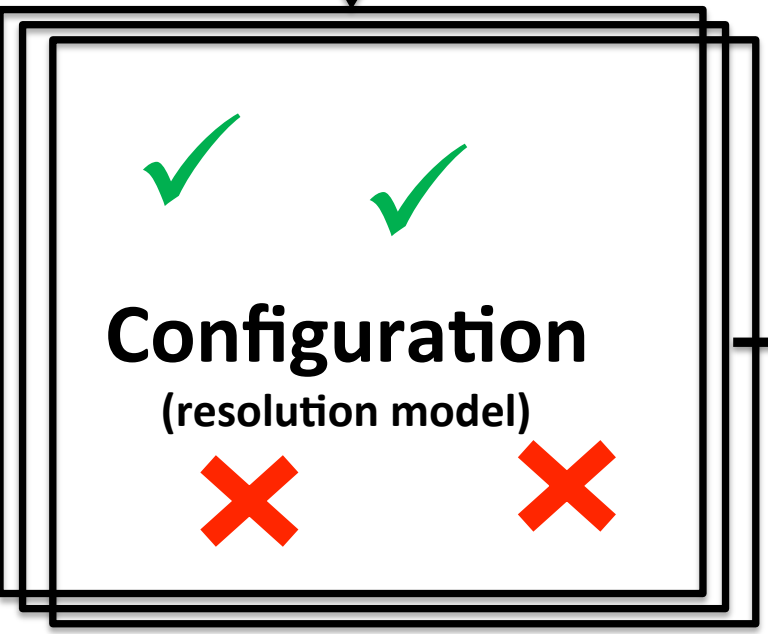


Variability Abstraction Model (VAM)

Variability Realization Model (VRM)



Domain Artefacts (e.g., models)



Configuration

(resolution model)

Software Generator

(derivation engine)

Mapping: an example

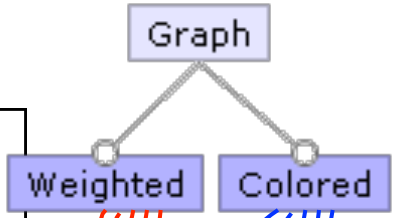
```
class Graph {
  Vector nv = new Vector(); Vector ev = new Vector();
  Edge add(Node n, Node m) {
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); ev.add(e);
    e.weight = new Weight();
    return e;
  }
  Edge add(Node n, Node m, Weight w)
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m);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

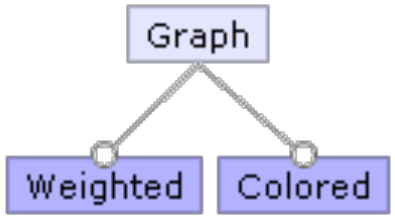
```
class Node {
  int id = 0;
  Color color = new Color();
  void print() {
    Color.setDisplayColor(color);
    System.out.print(id);
  }
}
```

```
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() { ... } }
```





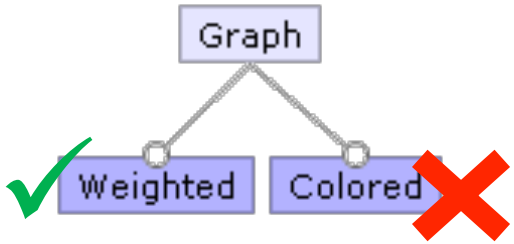

```
class Graph {
  Vector nv = new Vector(); Vector ev = new Vector();
  Edge add(Node n, Node m) {
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); ev.add(e);
    /*if[WEIGHT]*/
    e.weight = new Weight();
    /*end[WEIGHT]*/
    return e;
  }
  /*if[WEIGHT]*/
  Edge add(Node n, Node m, Weight 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]*/
```

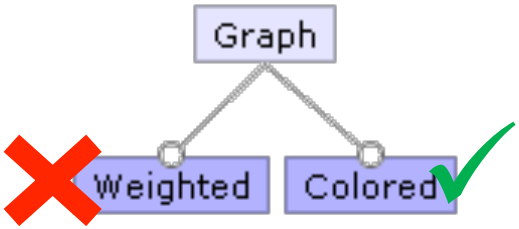



```
class Graph {
  Vector nv = new Vector(); Vector ev = new Vector();
  Edge add(Node n, Node m) {
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); ev.add(e);
e.weight = new Weight();
return e;
  }
Edge add(Node n, Node m, Weight w)
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); ev.add(e);
    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() { ... } }
```



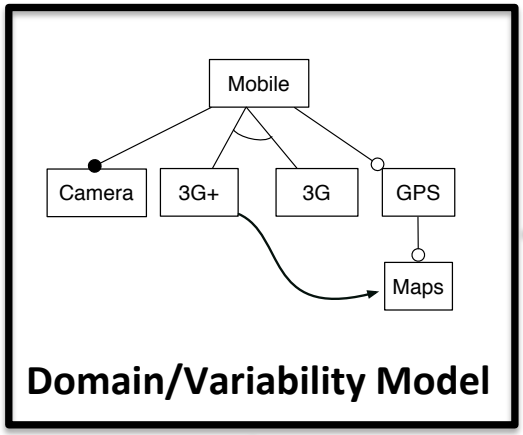

```
class Graph {
  Vector nv = new Vector(); Vector ev = new Vector();
  Edge add(Node n, Node m) {
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); ev.add(e);
return e;
  }
void print() {
    for(int i = 0; i < ev.size(); i++) {
      ((Edge)ev.get(i)).print();
    }
  }
}
```

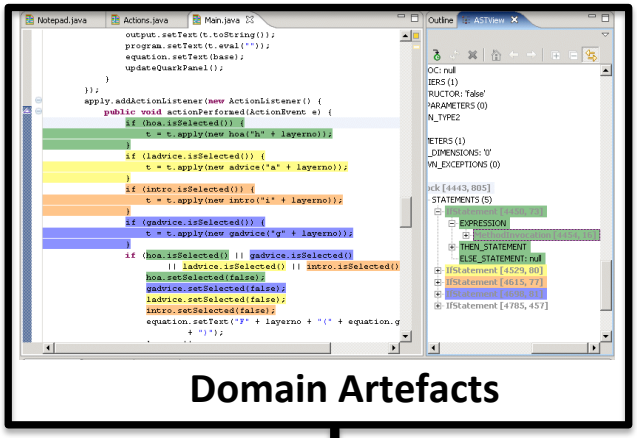
```
class Edge {
  Node a, b;
  Color color = new Color();
Edge(Node _a, Node _b) { a = _a; b = _b; }
  void print() {
Color.setDisplayColor(color);
a.print(); b.print();
}
}
```

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

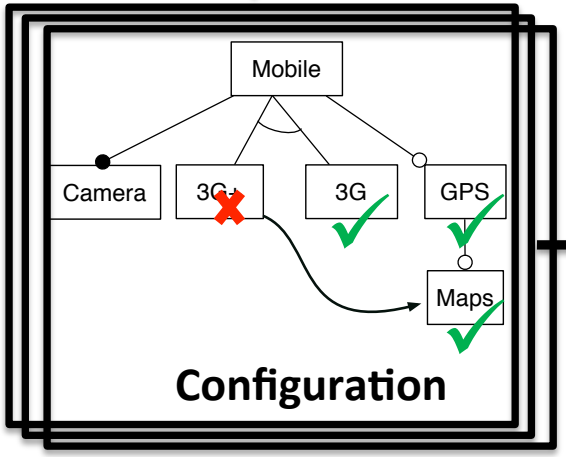
```
class Node {
  int id = 0;
Color color = new Color();
void print() {
Color.setDisplayColor(color);
System.out.print(id);
  }
}
```

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

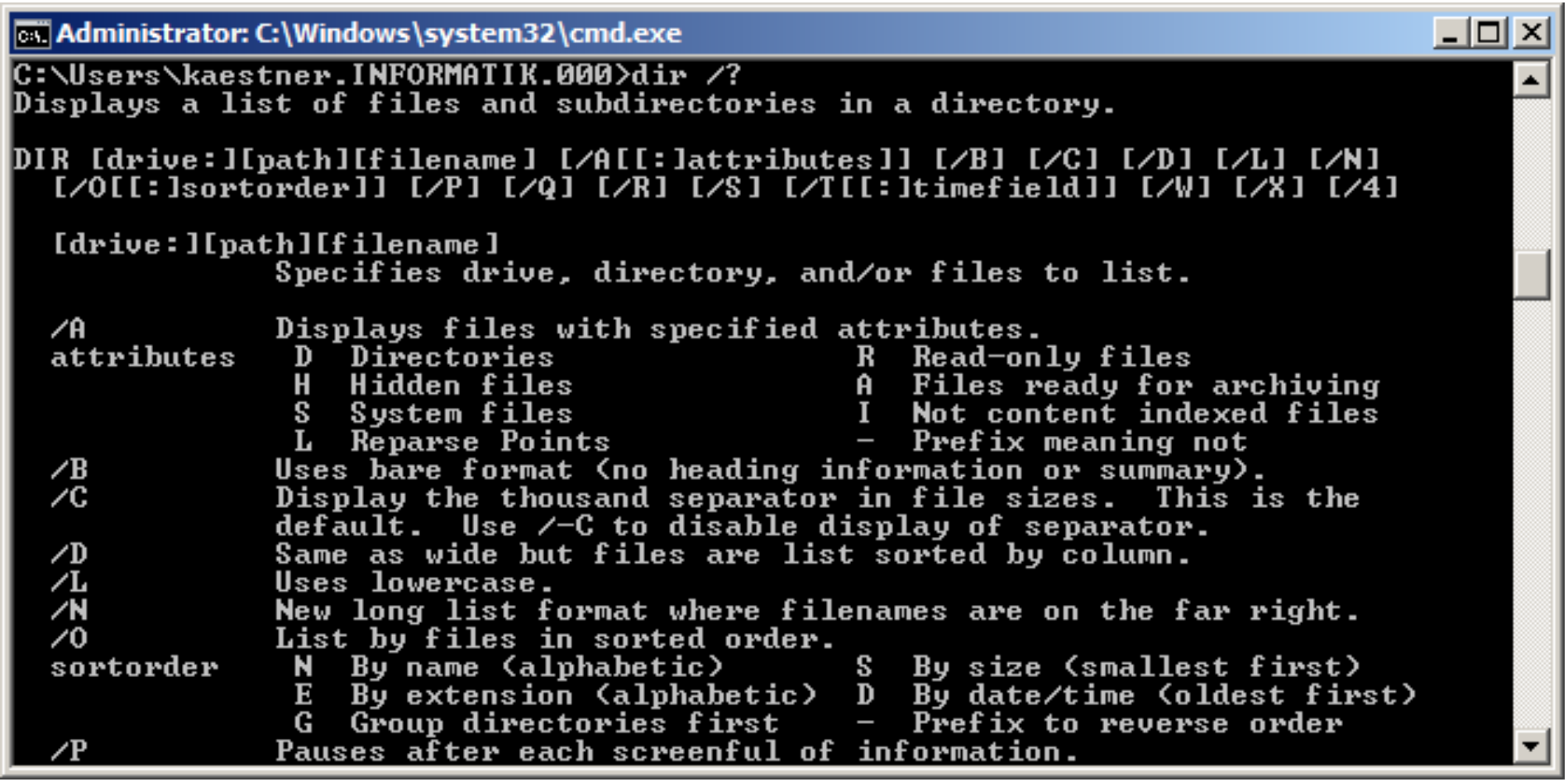
Factoring out commonality

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[[:]attributes]] [/B] [/C] [/D] [/L] [/N]
[/O[[:]sortorder]] [/P] [/Q] [/R] [/S] [/T[[:]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_c
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     }
```

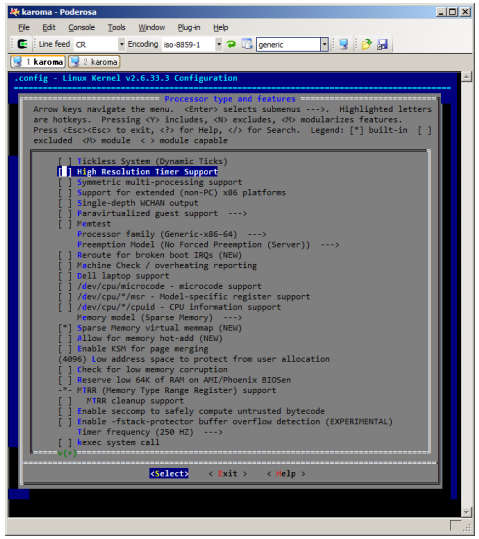
Global configuration

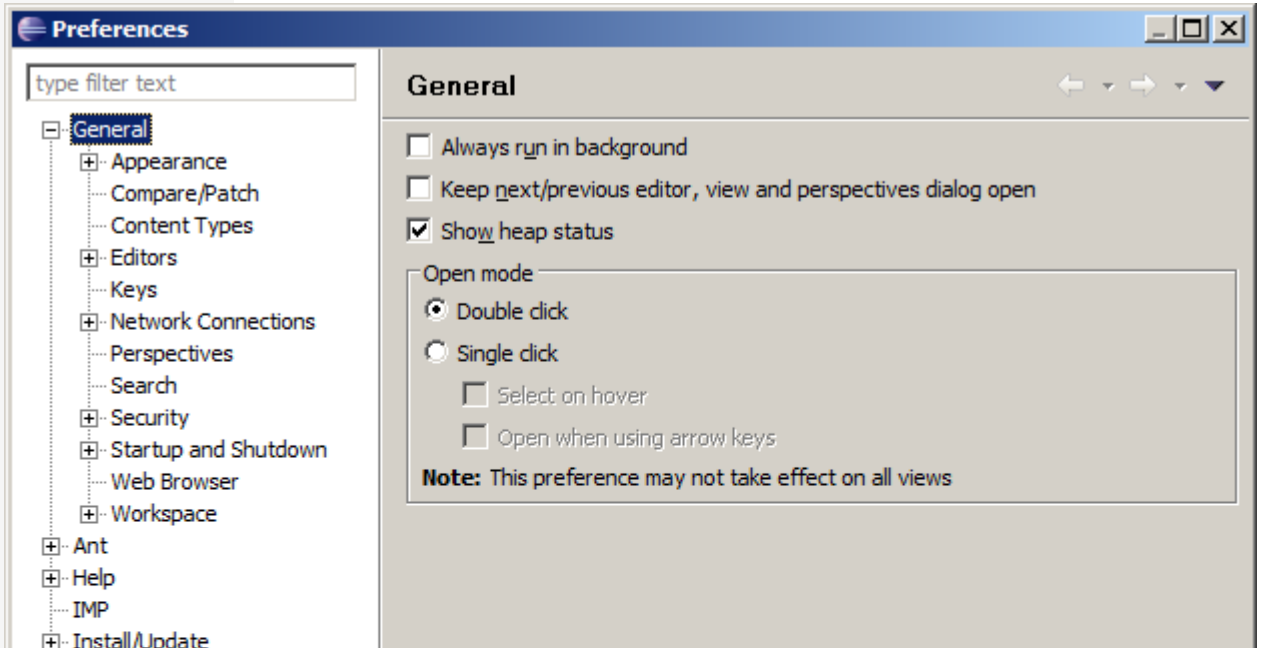
```
class Config {
  public static boolean isLogging = false;
  public static boolean isWindows = false;
  public static boolean isLinux = true;
}
class Main {
  public void foo() {
    if (isLogging)
      log(„running foo()“);
    if (isWindows)
      callWindowsMethod();
    else if (isLinux)
      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;
#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.intreqr, 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);
.......
```

cyberstormII.c

```
....
static void dma_dump_state(struct NCR_ESP *esp)
{
        ESPLOG(("esp%d: dma -- cond_reg<%02x>\n",
                esp->esp_id, ((struct cyberII_dma_registers *)
                                        (esp->dregs))->cond_reg));
        ESPLOG(("intreq:<%04x>, intena:<%04x>\n",
                custom.intreqr, custom.intenar));
}

static void dma_init_read(struct NCR_ESP *esp, __u32 addr, int
        length)
{
        struct cyberII_dma_registers *dregs =
                (struct cyberII_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

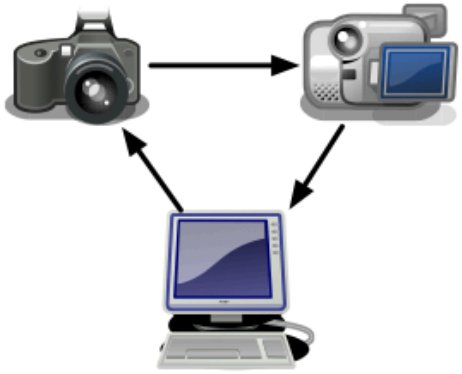
Clone existing code and fix low level platform interaction

+ 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

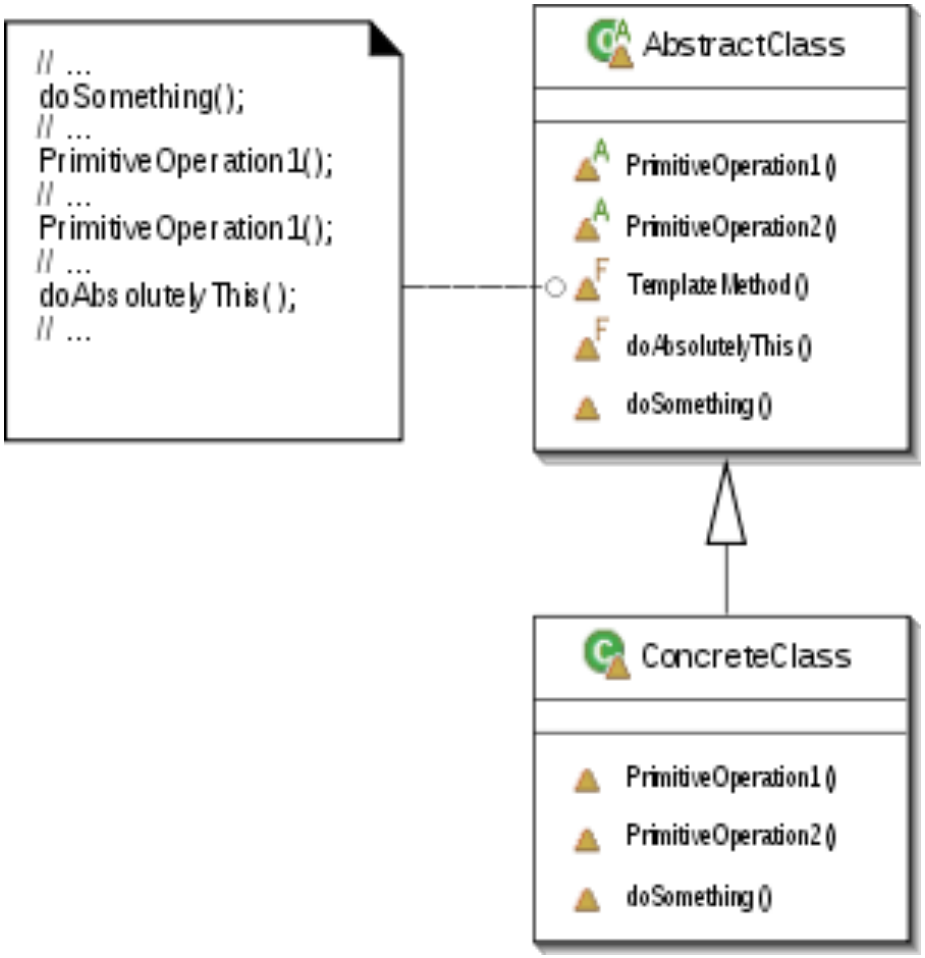
Factory

Strategy

Decorator

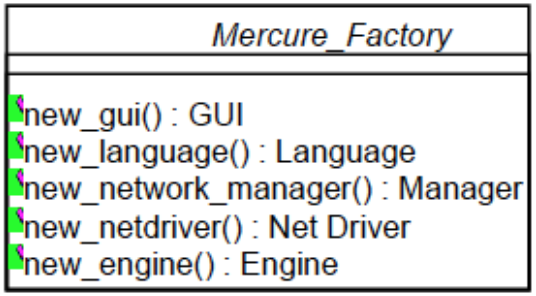
....

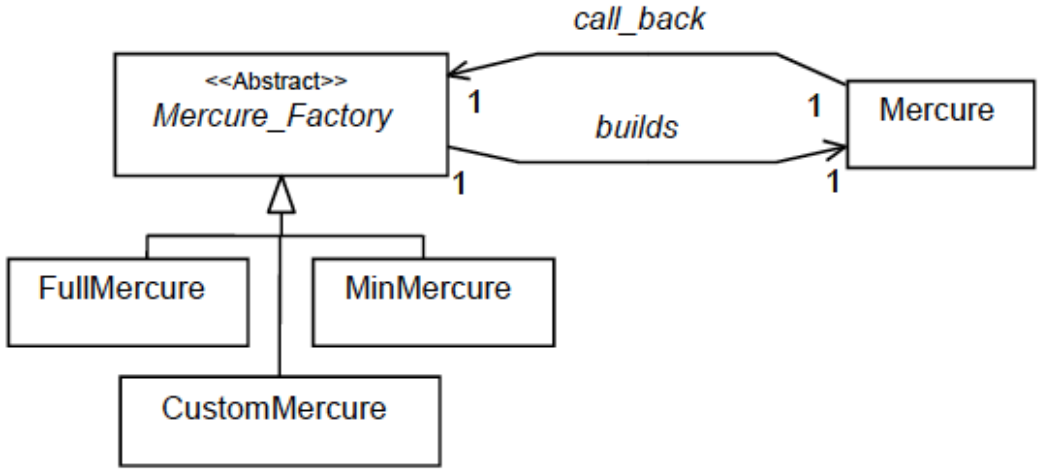
Template Method

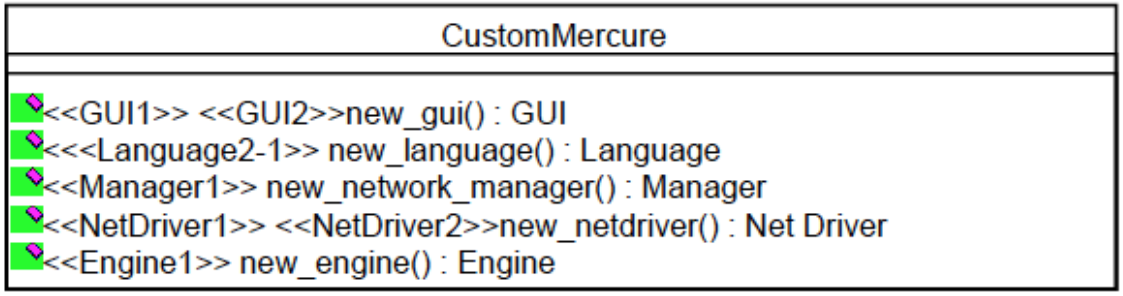


The decision model

- The Abstract Factory Design Pattern
  - [Gamma et al 95]







API

Framework

Plugin-based systems

(Active) Annotations

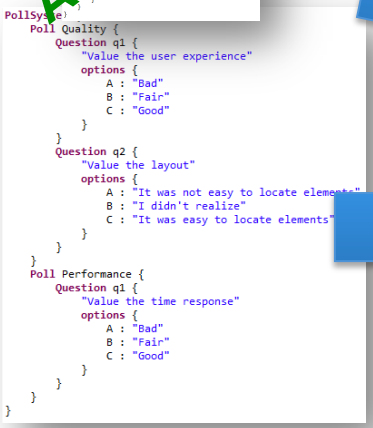
can have parameters

Metamodeling and Domain-Specific Languages

Commonalities

TP 3

Another DSL



```
PollSystem
    Poll Quality {
        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"
            }
        }
    }
    Poll Performance {
        Question q1 {
            "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

Generator

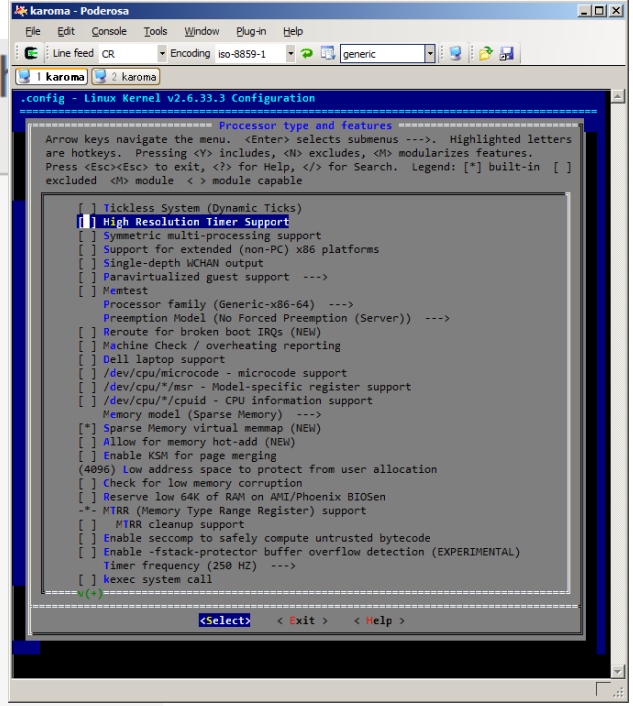
TP 5

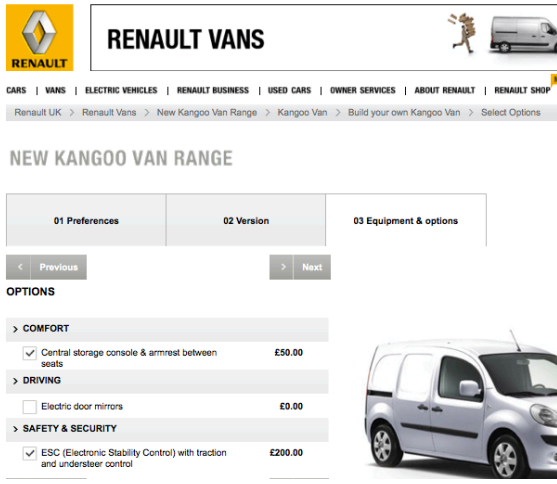
Model-to-Text

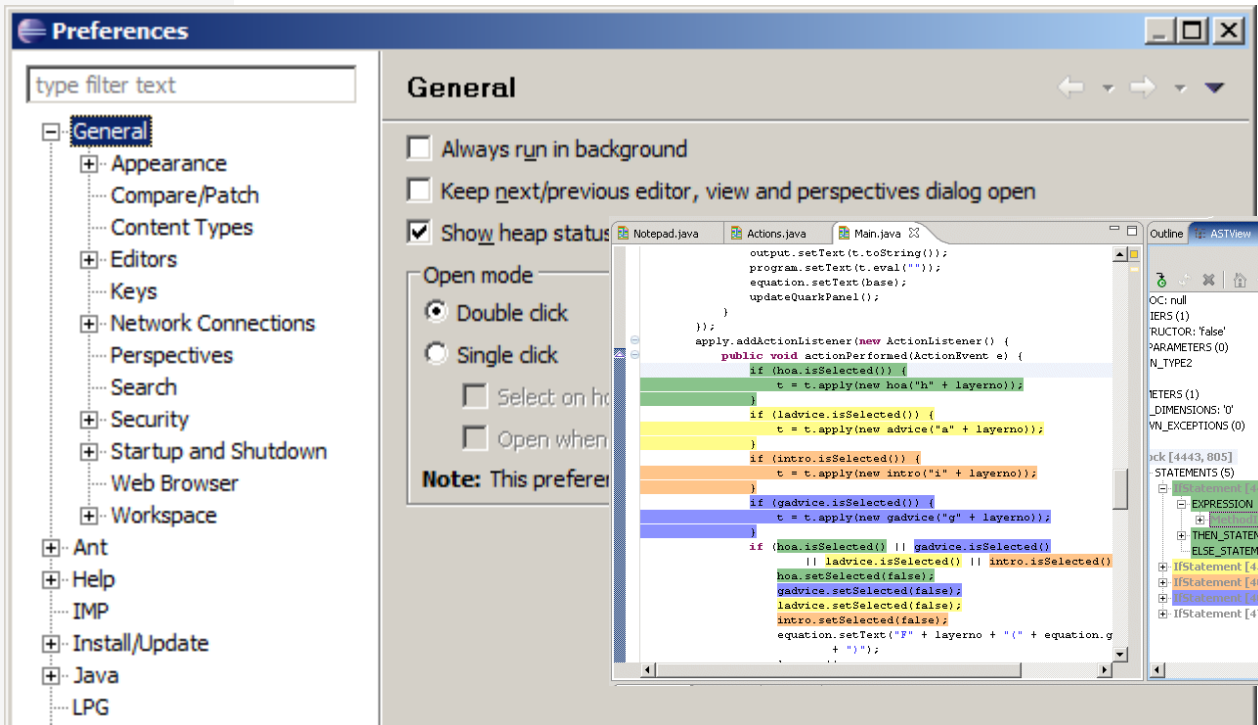
httpd.conf -- win32 Apach

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>
```



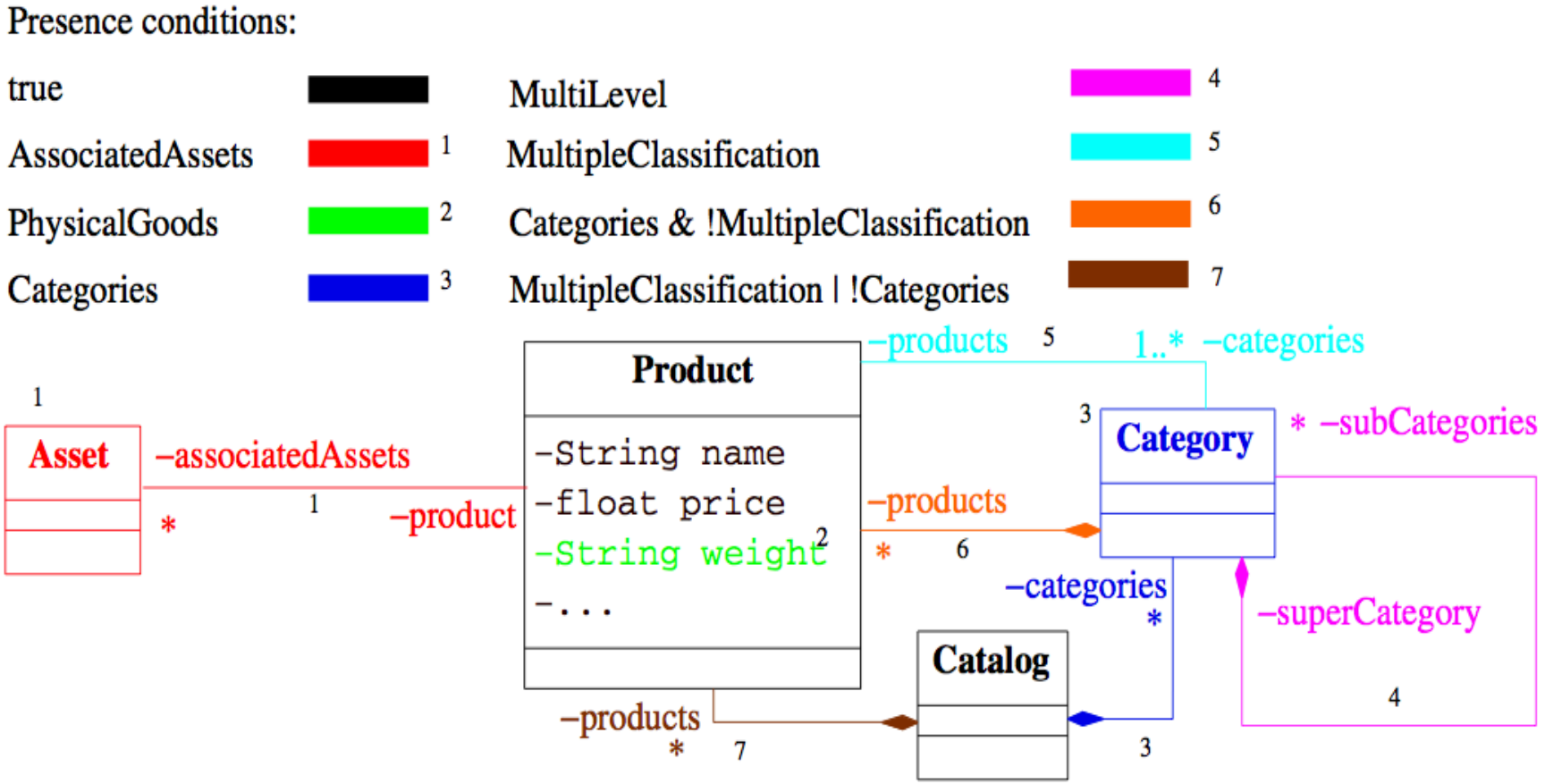





Unused flexibility

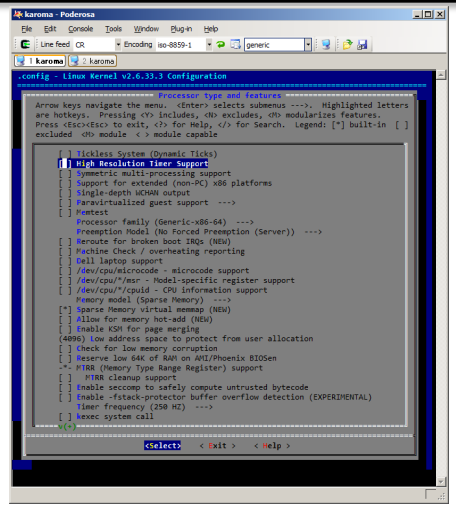

Illegal variant

Domain Design

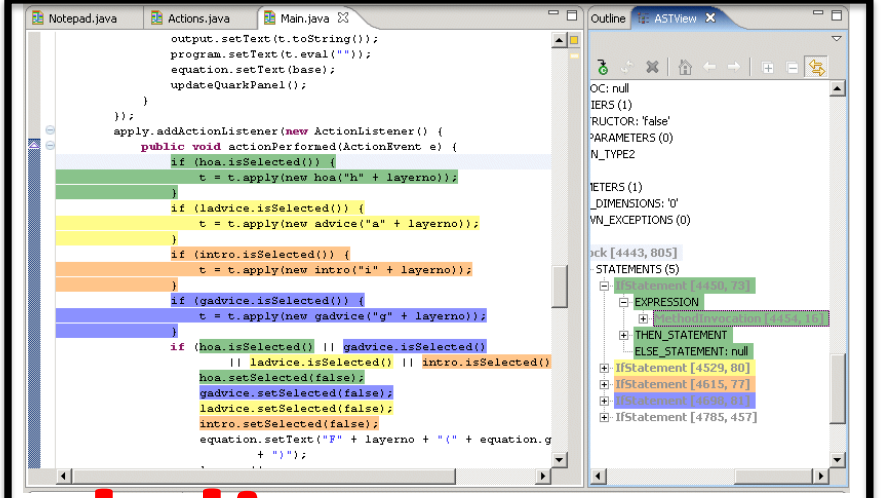


Czarnecki et al. (GPCE'05)

Feature Models



Variability Model



Domain Artefacts (e.g., source code)

Modeling variability is crucial

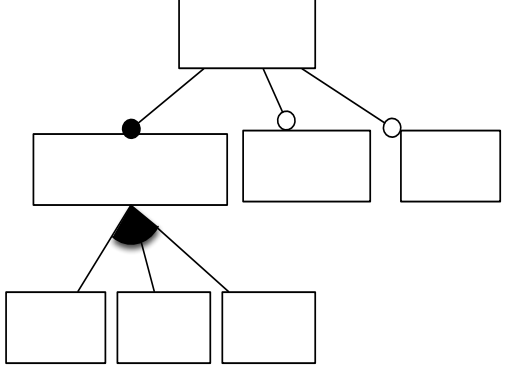
Configuration

Software Generator


Unused flexibility

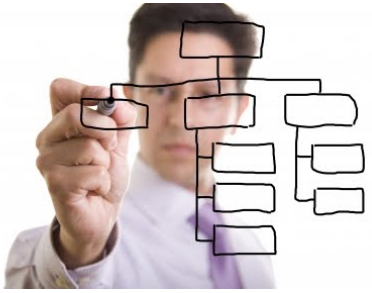

Illegal variant

Feature Model

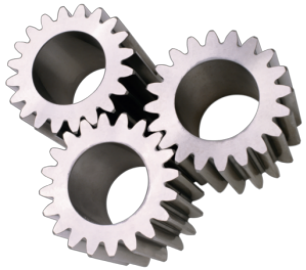


not, and, or, implies

Communicative



Analytic



Generative

Audi
Vorsprung durch Technik

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

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

1 Modèle | 2 Moteur | 3 Extérieur | 4 Intérieur | 5 Option | 6 Votre Audi

Audi
Vorsprung durch Technik

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

☑ Régulateur de vitesse		320,65 EUR
☐ Système d'aide au stationnement APS avant / arrière		931,70 EUR
☐ Système d'aide au stationnement APS avant / arrière avec affichage dans l'écran MMI		1.373,35 EUR
☑ Système d'aide au stationnement Advanced : APS avant et arrière et caméra arrière		1.790,80 EUR
● Audi hill assist : assistance au démarrage en côte		Série

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

Audi
Vorsprung durch Technik

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

[+] Plein écran / Dimensions

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 **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		181,50 EUR
○ Pack Intenso Plus		3.100,00 EUR

- Extérieur
- Jantes & pneumatiques
- Intérieur
- Volants
- Sièges
- Sécurité & technique
- **Infotainment**

2.934,25 EUR

● Sans appareil de navigation — Série

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

Un aperç des équipements:

Mode expert

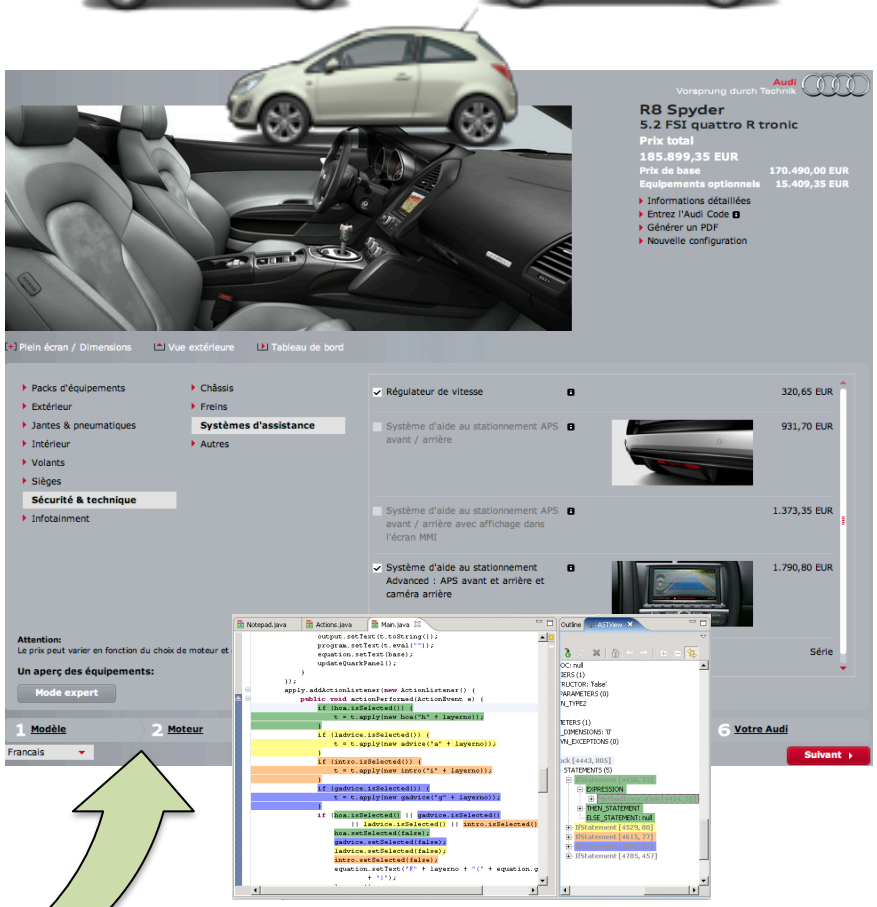
Réinitialiser la sélection

1 Modèle | 2 Moteur | 3 Extérieur | 4 Intérieur | 5 Option | 6 Votre Audi

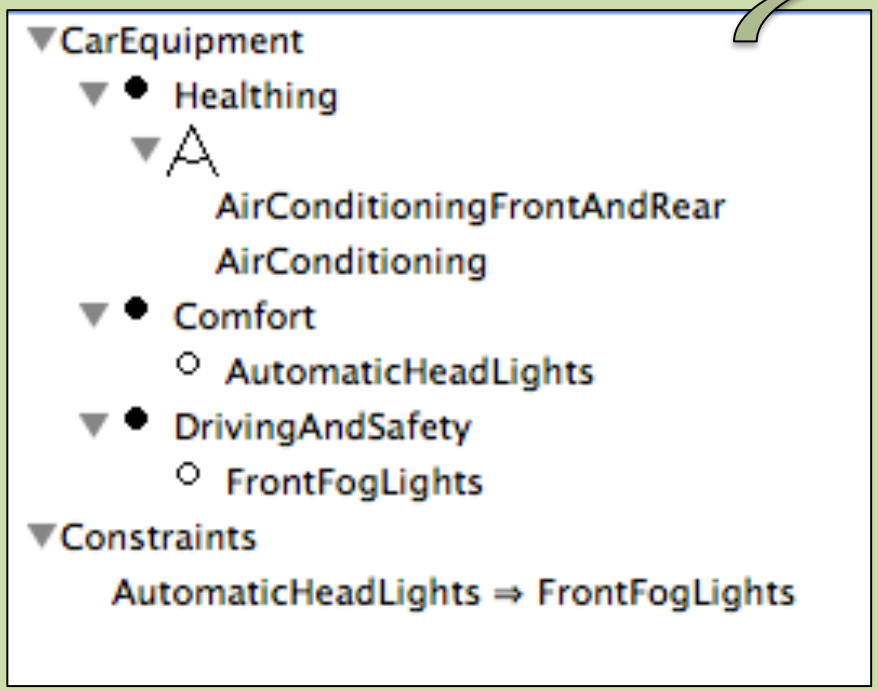
Francais

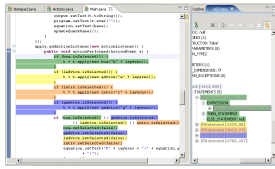
Suivant

Feature Models



Feature Models (Background)

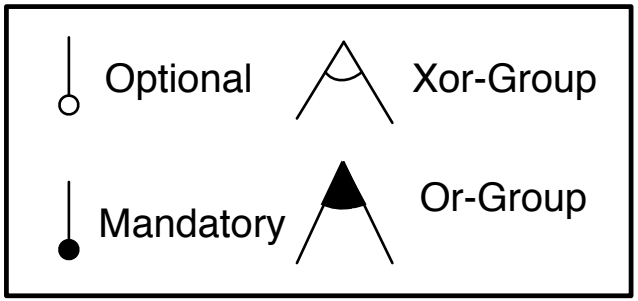




Hierarchy: rooted tree

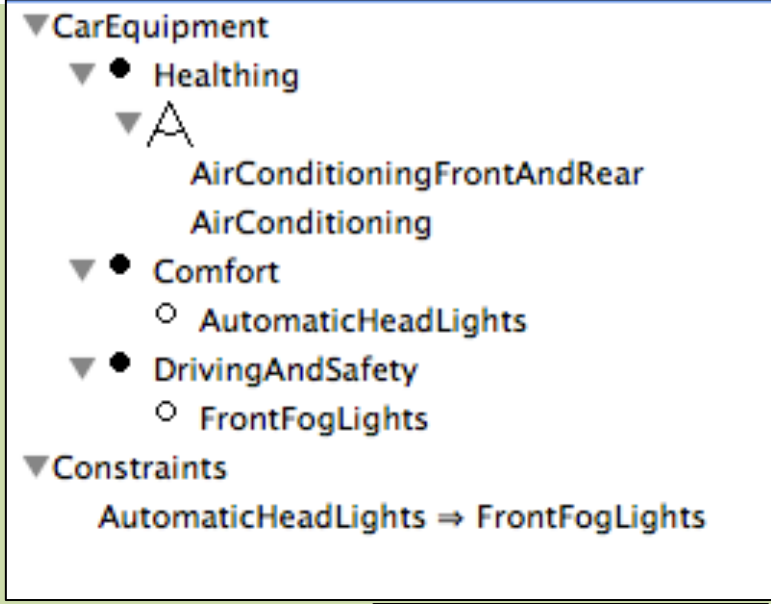
Variability:

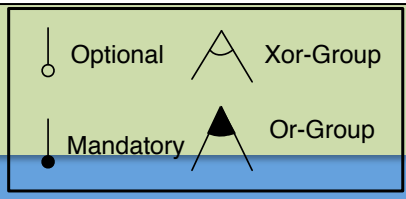
- mandatory,
- optional,
- Groups: exclusive or inclusive features
- Cross-tree constraints



SPLC12Scripts Model | SPLC12Scripts.config

- CarEquipment (valid, 1 possible configurations)
  - Healthing
    - AirConditioningFrontAndRear
    - AirConditioning
  - Comfort
    - AutomaticHeadLights
  - DrivingAndSafety
    - FrontFogLights





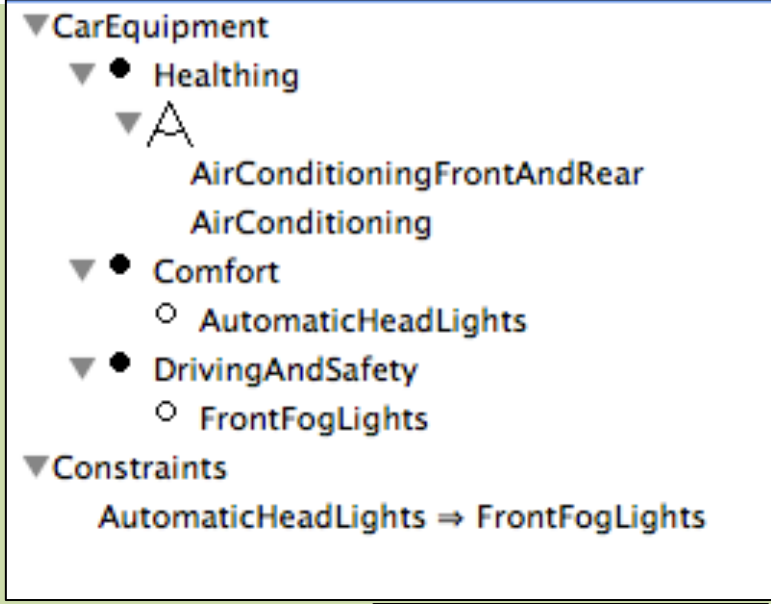
Hierarchy + Variability
=
set of valid configurations

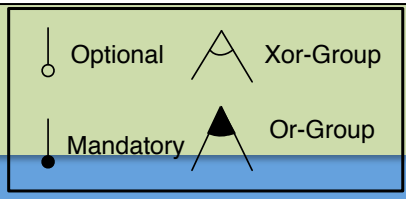
configuration = set of features selected

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

SPLC12Scripts Model | SPLC12Scripts.config

- CarEquipment (valid, 1 possible configurations)
  - Healthing
    - AirConditioningFrontAndRear
    - AirConditioning
  - Comfort
    - AutomaticHeadLights
  - DrivingAndSafety
    - FrontFogLights

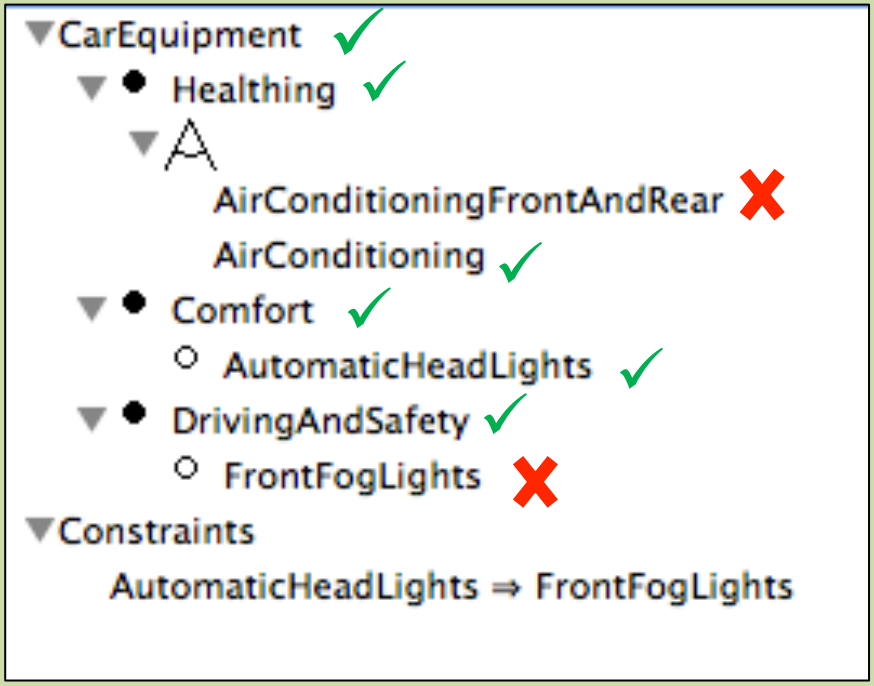


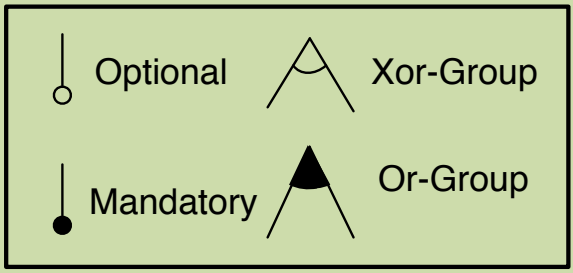


Hierarchy + Variability
=
set of valid configurations

configuration = set of features selected

{CarEquipment, Comfort, DrivingAndSafety, Healthing, AirConditioning}

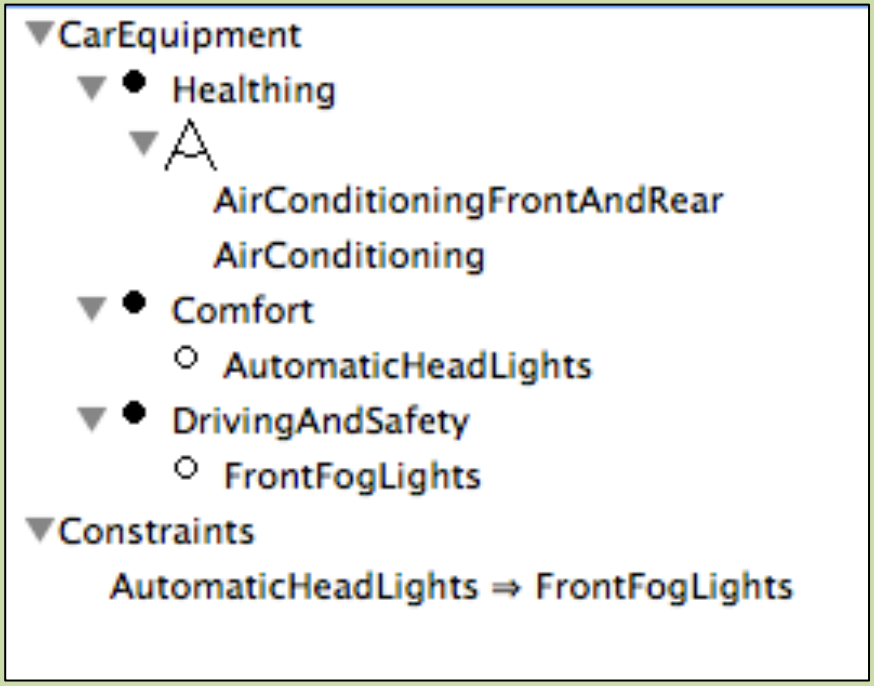


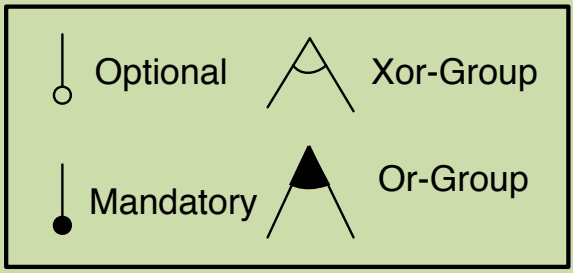


Hierarchy + Variability
=
set of valid configurations

configuration = set of features selected

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





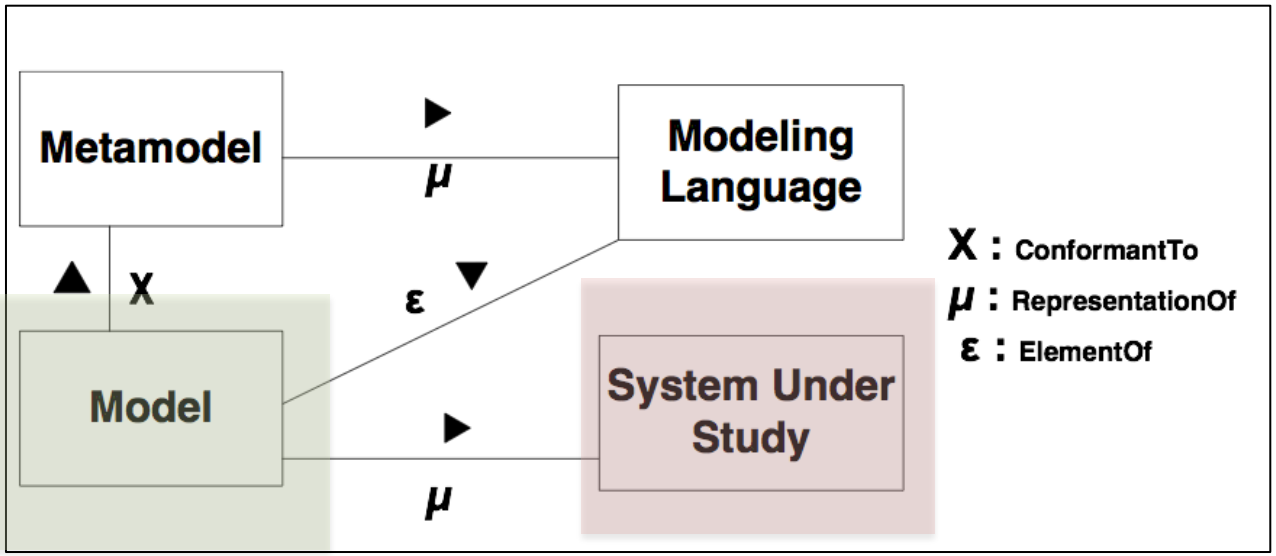
Hierarchy + Variability
=
set of valid configurations

{CarEquipment, Comfort, DrivingAndSafety, Healthing}

X

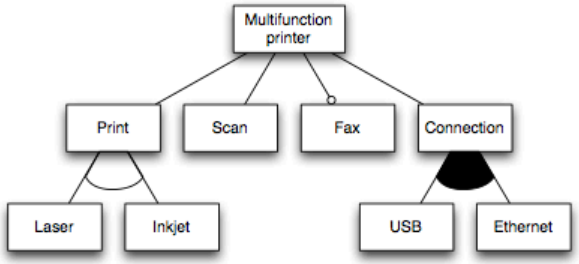
{AirConditioning, FrontFogLights}
{AutomaticHeadLights, AirConditioning, FrontFogLights}
{AutomaticHeadLights, FrontFogLights, AirConditioningFrontAndRear}
{AirConditioningFrontAndRear}
{AirConditioning}
{AirConditioningFrontAndRear, FrontFogLights}

Feature Models

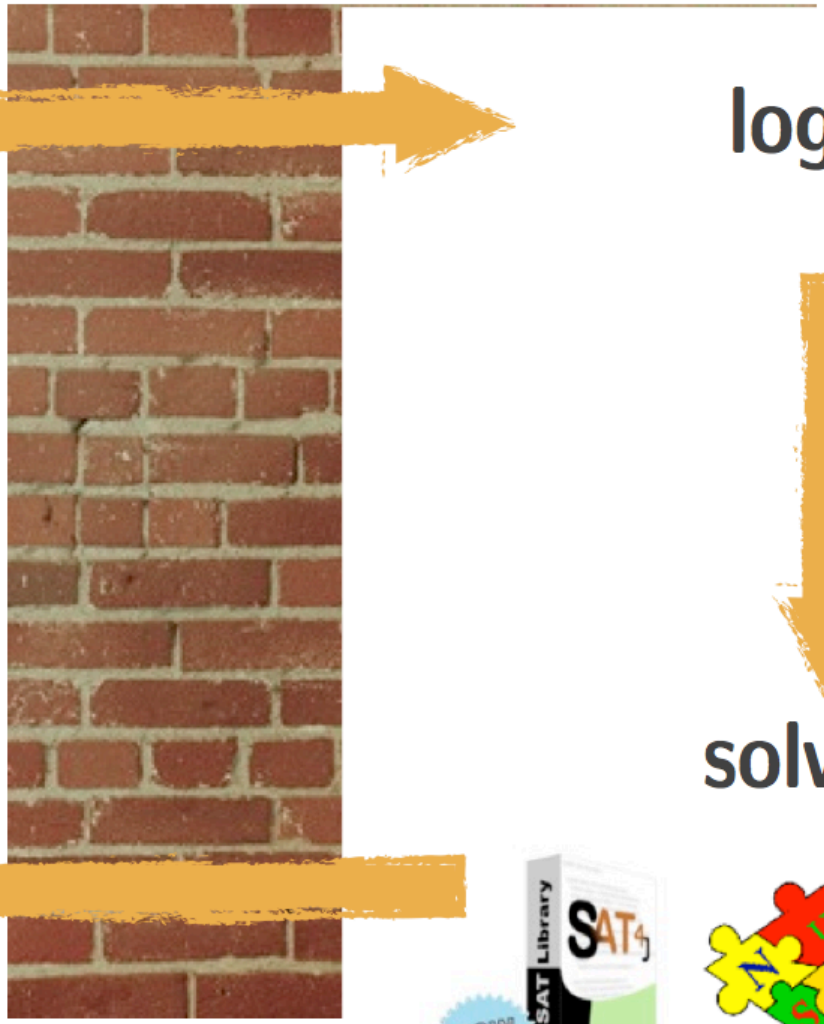


- CarEquipment
  - Healthing
    - AirConditioningFrontAndRear
    - AirConditioning
  - Comfort
    - AutomaticHeadLights
  - DrivingAndSafety
    - FrontFogLights
- Constraints
  - AutomaticHeadLights ⇒ FrontFogLights

Typical implementations



result

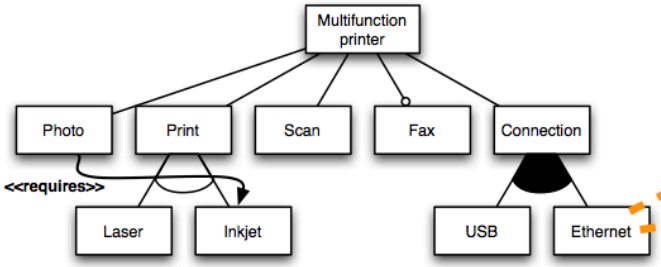


logics

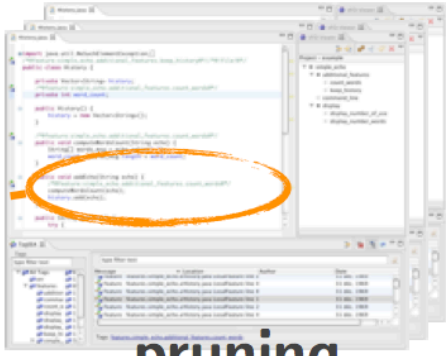
solvers

Product Derivation

feature model



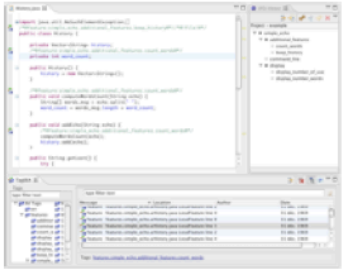
variable model and code assets



pruning,
composition,
weaving,
transformation
...

configuration

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



product spec

product

Bref
as a product line


bref30ans.canalplus.fr/#c
ETAPE 2 : CHOISIS 3 BONS SOUVENIRS
JE NE VEUX PAS CHOISIR
C'ÉTAIT UN MESSAGE À CARACTÈRE INFORMATIF
BURGER QUIZ
JAMEL SHOW
LE DÉZAPPING DU BEFORE BEST OF


ETAPE 3 : JE REGARDE MON EPISODE UNIQUE
DEJÀ 1 796 108 EPISODES GENERES.
MICHEL DENISOT
DIRECTEUR ARTISTIQUE
DES CESAR
HD

How MDE (IDM) can help

Software Product Line Engineering

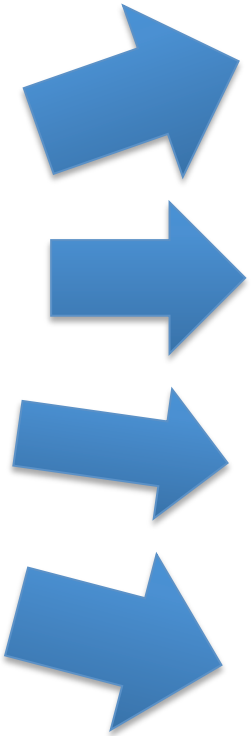
Generative approach

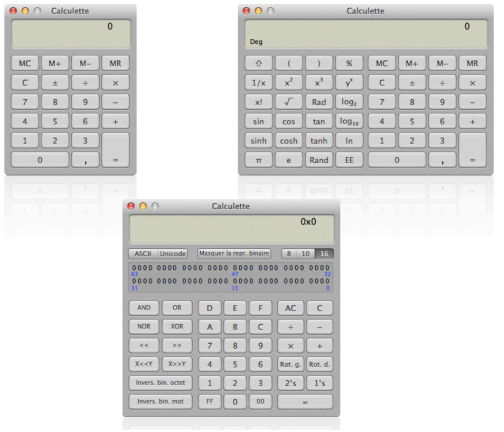
- Programming the generation of programs
  - Very old practice
  - Metaprogramming: generative language and target language are the same
    - Reflection capabilities

- Generalization of this idea:
  - from a specification written in one or more textual or graphical domain-specific languages
  - you generate **customized variants**

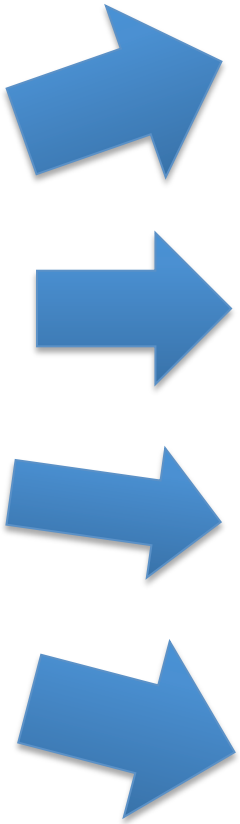
Modeling and implementing system families such that a desired system can be automatically generated from a specification written in one or more textual or graphical domain-specific languages.

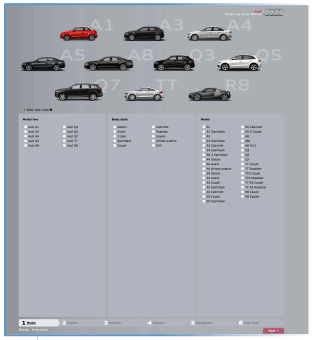
Models And Languages

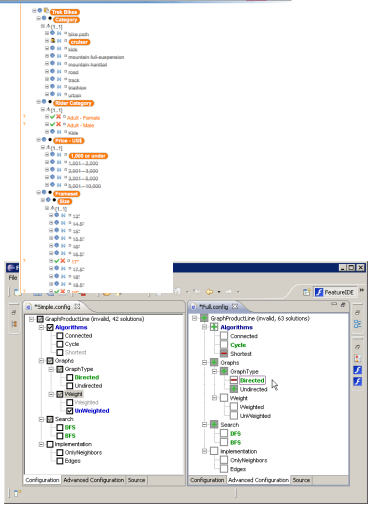


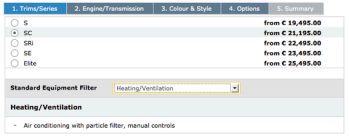


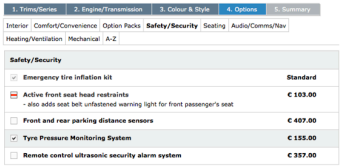
Models And Languages

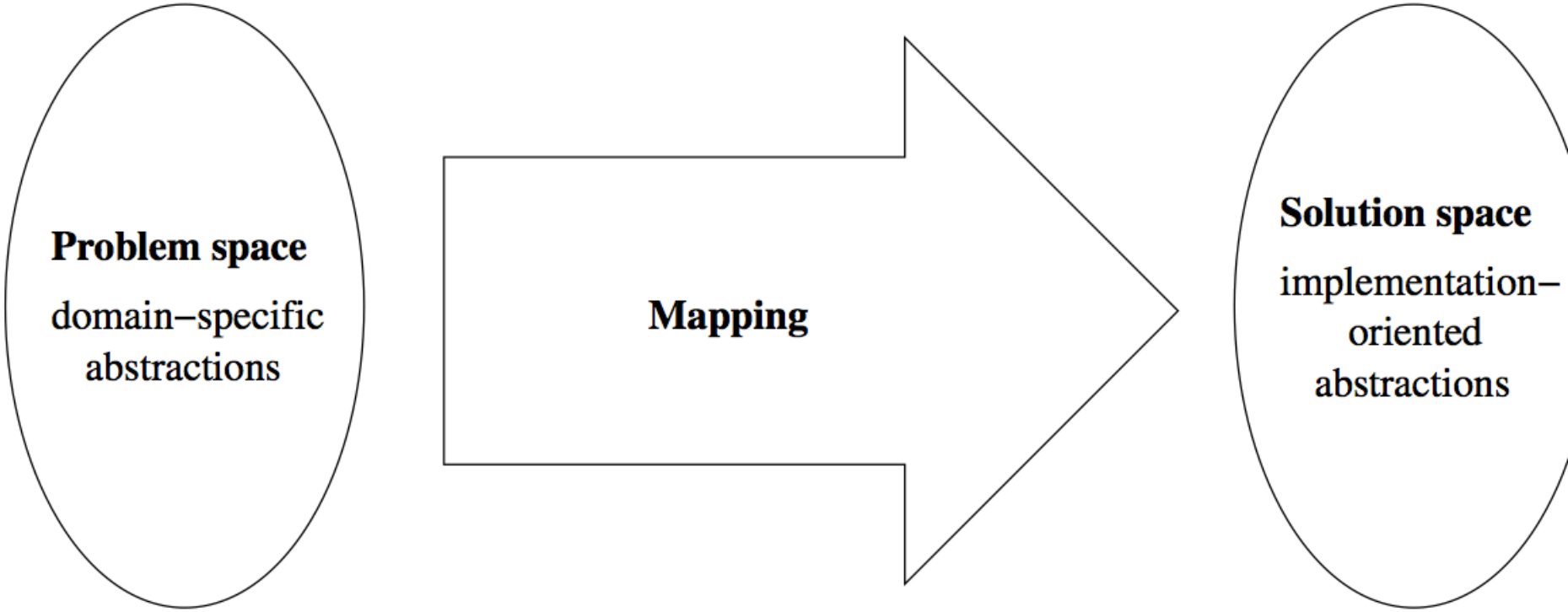




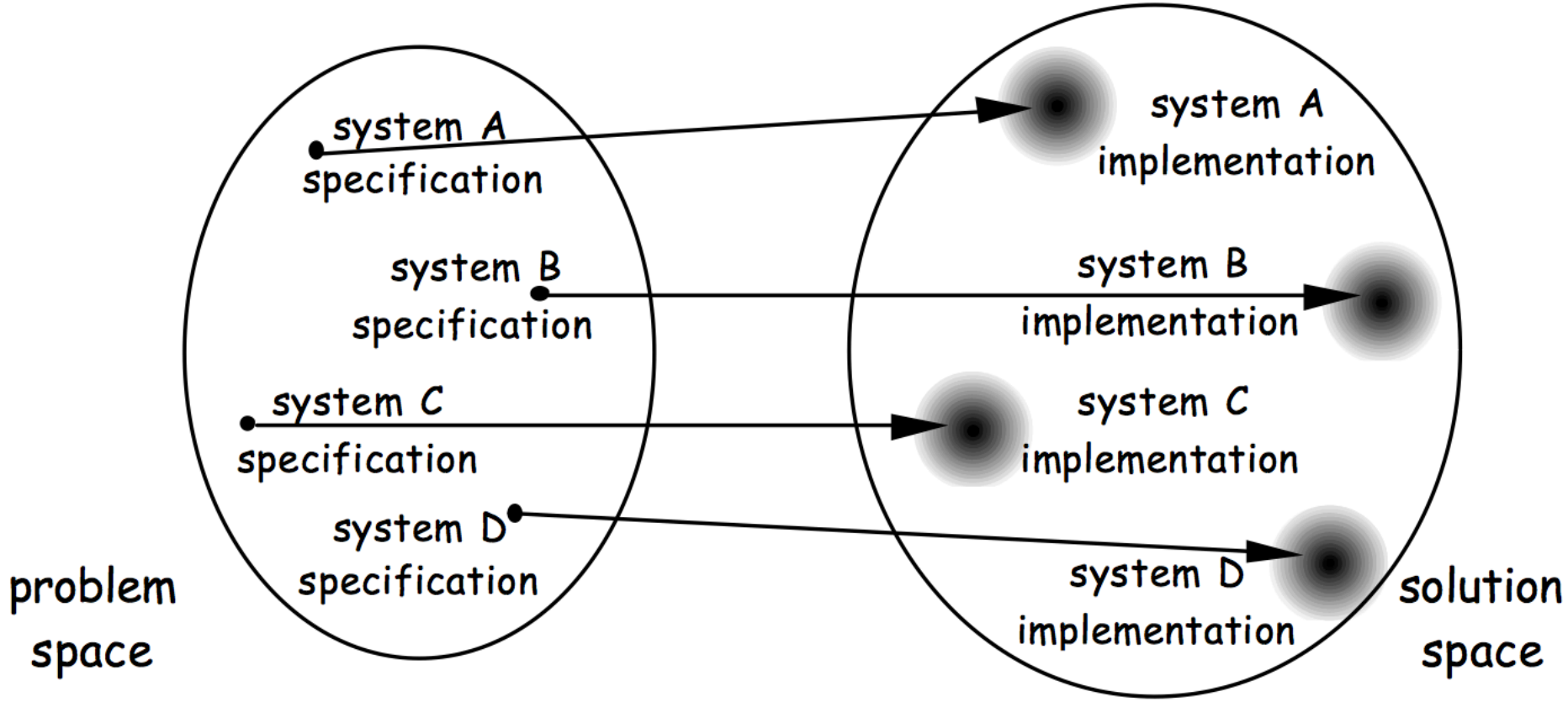








[Czarnecki and Eisenecker 2000]



[Czarnecki, PhD thesis]

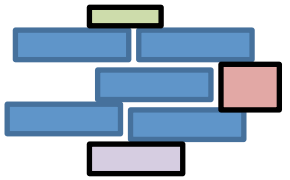
Developing Product Lines

Metamodels, DSLs, and Transformations to the rescue

- Domain Engineering
  - Domain Models
  - Level of abstraction
  - Domain-specific modeling languages
    - (visual or textual) syntacs, 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