

Variability and Software Product Lines (an overview)

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Maître de Conférences

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Material

[https://github.com/FAMILIAR-project/
HackOurLanguages-SIF](https://github.com/FAMILIAR-project/HackOurLanguages-SIF)

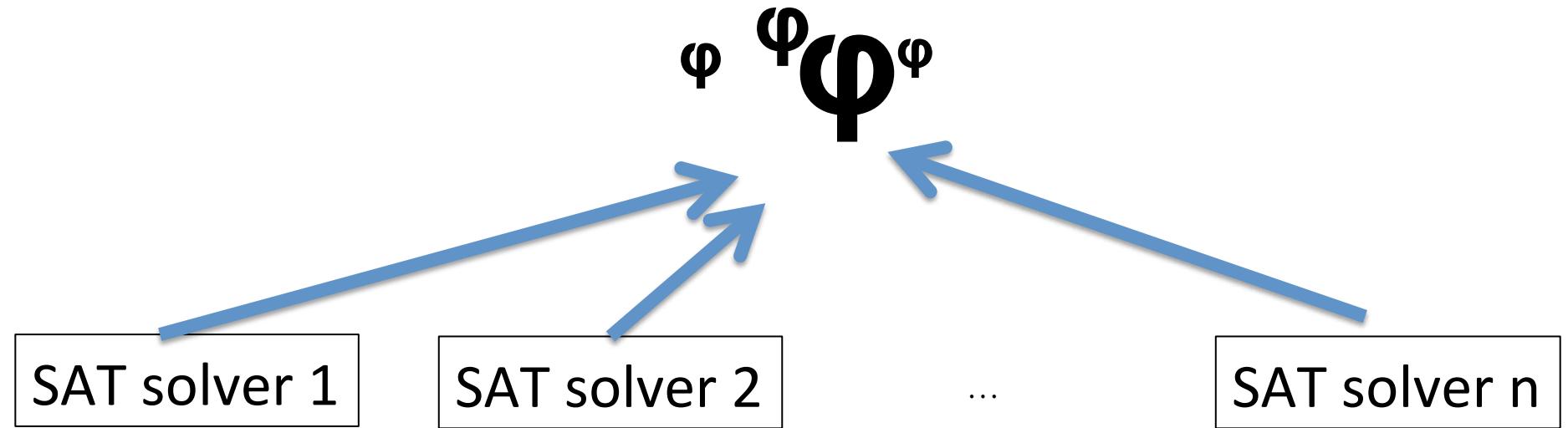
Plan

- 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
 - Syntax, semantics, automated reasoning, synthesis

Contract

- The idea of software product lines and variability
 - You will be able to recognize this class of systems
 - Aware of the complexity, the specific development process, and existing techniques
- Feature modeling
 - A widely used language for modeling product lines and configurable systems in a broad sense
- Composing/Decomposing feature models with a domain-specific language
- Reverse engineering variability models

Comparing solver variants' performance



You Retweeted



Thomas Thüm

@ThomasThuem

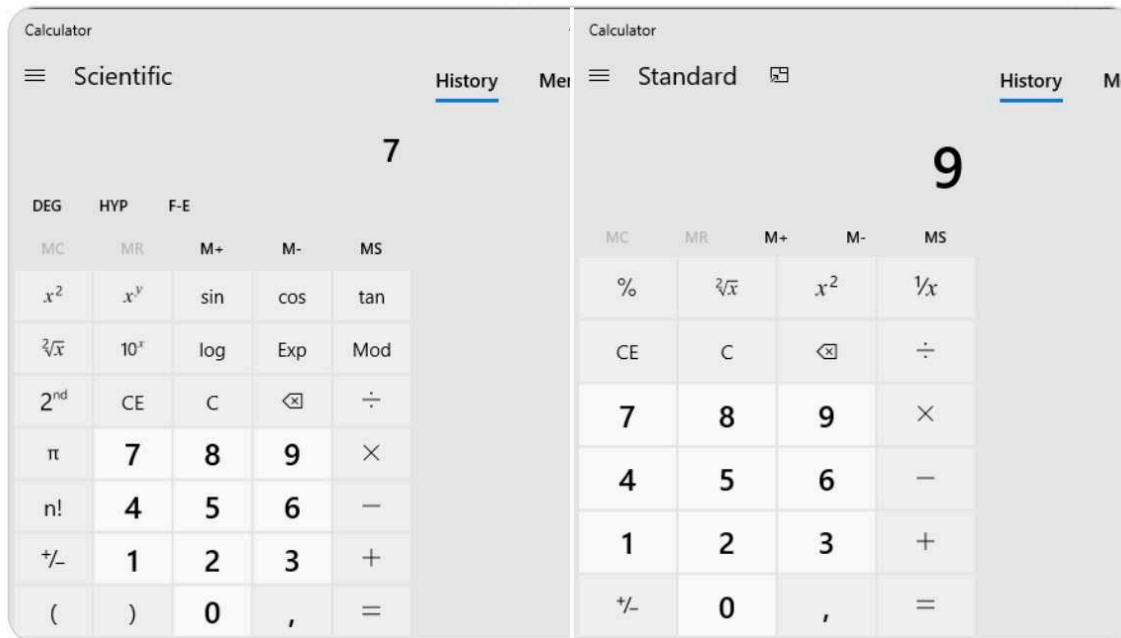
▼

How much is $1 + 2 * 3$?

According to [@Windows 10](#), the result depends on the mode that you have chosen!!!!

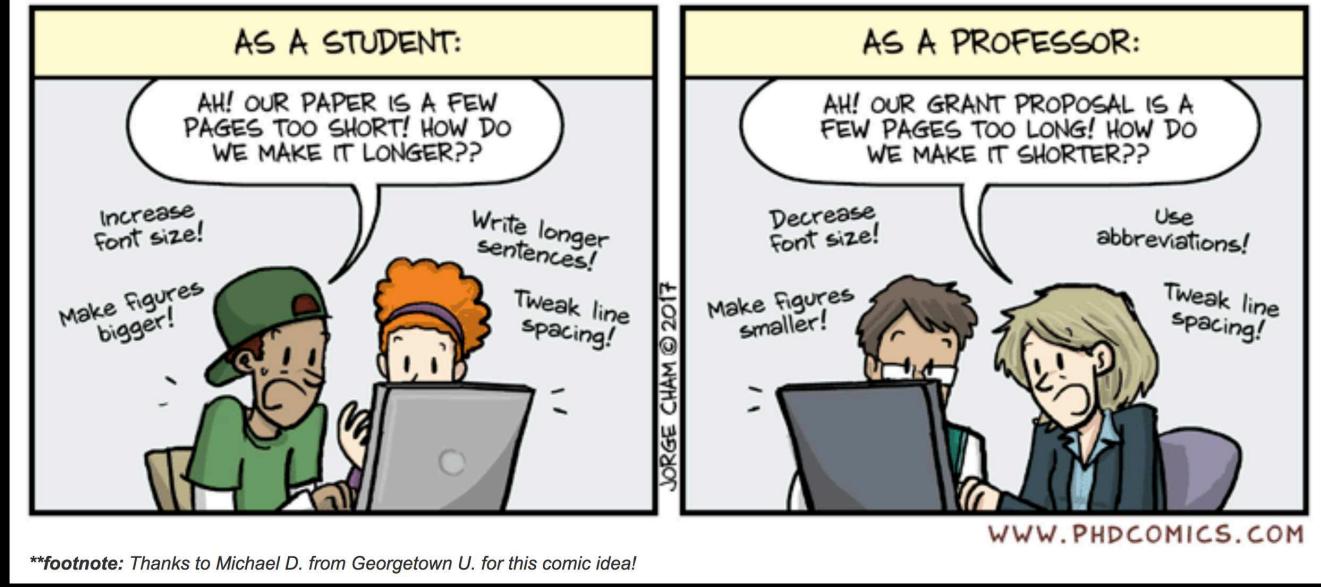
The Calculator app gives the correct result in Scientific mode and a wrong result with the default mode called Standard.

I bet this caused thousands of wrong calculations!



- **What are software variability and software product lines? Where are they? How are they developed? What are the problems, solutions, and challenges?**
 - We will explain, using real-world examples, how variability is realized in the wild and why innovation is needed to improve the situation

PAGE LIMITS



***footnote:* Thanks to Michael D. from Georgetown U. for this comic idea!

<http://phdcomics.com/comics.php?f=1971>

Vary \LaTeX : Learning Paper Variants That Meet Constraints

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Successfully submitted for VaMoS'18

(on time and meeting formatting instructions)
and then accepted

(live demonstration)

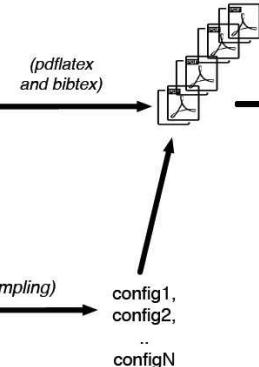
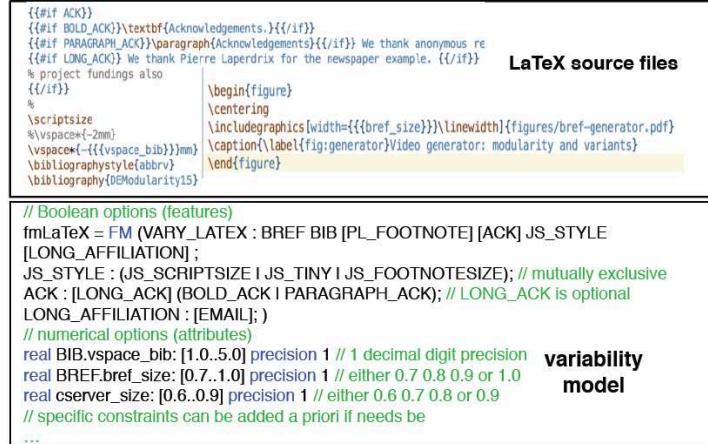
Two case studies

- FSE paper (see demonstration)
 - Page limit: 4
 - Accuracy: ~85% with 40 papers in the training set (there are 73,440 valid configurations)
- Another case: curriculum vitae generation
 - 18 pages limit; 5 Boolean options; full generation, only 32 papers (not need to learn here)

(Software Product Line) Process



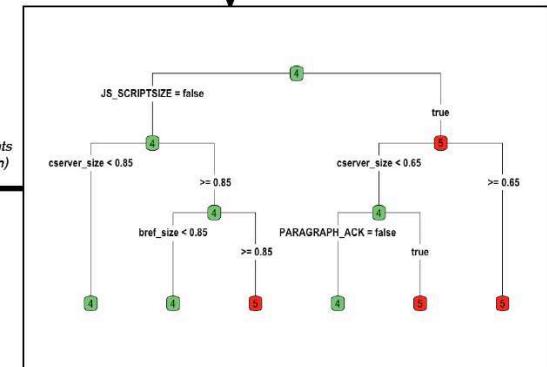
① Variability annotations and modeling



② Paper variants building and measurements

JS_SCRIPTSIZE	JS_STYLE	JS_TINY	LONG_ACK	LONG_AFFILIATION	PARAGRAPH_ACK	PL_FOOTNOTE	VARY_LATEX	bref_size	cserver_size	vspace_bib	nbPages	
false	true	true	true	false	false	false	true	0.7	0.9	4.0	4	✓
false	true	true	false	false	false	false	true	0.8	0.6	2.2	4	✓
false	true	true	false	false	false	false	true	0.9	0.6	2.3	4	✓
false	true	true	true	true	true	true	true	0.7	0.8	1.1	4	✓
true	true	false	false	true	false	true	true	0.8	0.9	1.8	5	✗
true	true	false	false	true	false	false	true	0.7	0.8	2.8	5	✗
true	true	false	false	false	false	false	true	0.7	0.8	2.9	5	✗
false	true	true	false	true	false	false	true	0.9	0.7	4.9	4	✓
true	true	false	true	true	false	true	true	1.0	0.7	1.7	5	✗
true	true	false	false	false	false	true	true	1.0	0.6	1.8	5	✗
true	true	false	false	true	false	true	true	0.7	0.6	2.8	4	✓

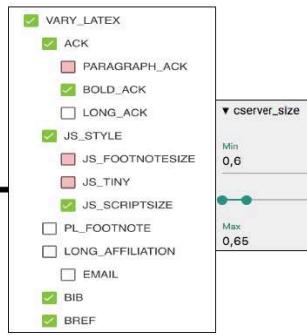
③ Machine Learning (Classification problem)



// same original variability model
fmLaTeX = FM (VARY_LATEX ...)
// ...
real cserver_size: [0.6..0.9] precision 1
// constraints (^ is AND, ! is NOT, => is IMPLIES)
// we negate the paths leading to class "5" (non-acceptable)
// !(JS_SCRIPTSIZE ^ cserver_size >= 0.65) or more readable:
(JS_SCRIPTSIZE => cserver_size < 0.65) ^
!(JS_SCRIPTSIZE ^ cserver_size < 0.65 ^ PARAGRAPH_ACK)
// equivalent to
(JS_SCRIPTSIZE => (cserver_size < 0.65 => !PARAGRAPH_ACK)) ^
!(JS_SCRIPTSIZE ^ cserver_size >= 0.9 ^ bref_size >= 0.9)

variability model + constraints

④ Ready-to-configure paper



#1 Modeling variability features/ options, constraints, reasoning, solving



① Variability annotations and modeling

```
 {{#if ACK}}
{{#if BOLD_ACK}}\textbf{Acknowledgements.}{{/if}}
{{#if PARAGRAPH_ACK}}\paragraph{Acknowledgements}{{/if}} We thank anonymous re
{{#if LONG_ACK}} We thank Pierre Laperdrix for the newspaper example. {{/if}}
% project fundings also
{{/if}}
%
\scriptsize
% \vspace*{-2mm}
\hspace*{-{{vspace_bib}}}mm
\bibliographystyle{abbrv}
\bibliography{DEModularity15}
```

LaTeX source files

```
\begin{figure}
\centering
\includegraphics[width={{bref_size}}]\linewidth{figures/bref-generator.pdf}
\caption{\label{fig:generator}Video generator: modularity and variants}
\end{figure}
```

```
// Boolean options (features)
fmLaTeX = FM (VARY_LATEX : BREF BIB [PL_FOOTNOTE] [ACK] JS_STYLE
[LONG_AFFILIATION];
JS_STYLE : (JS_SCRIPTSIZE | JS_TINY | JS_FOOTNOTESIZE); // mutually exclusive
ACK : [LONG_ACK] (BOLD_ACK | PARAGRAPH_ACK); // LONG_ACK is optional
LONG_AFFILIATION : [EMAIL]; )
// numerical options (attributes)
real BIB.vspace_bib: [1.0..5.0] precision 1 // 1 decimal digit precision
real BREF.bref_size: [0.7..1.0] precision 1 // either 0.7 0.8 0.9 or 1.0
real cserver_size: [0.6..0.9] precision 1 // either 0.6 0.7 0.8 or 0.9
// specific constraints can be added a priori if needs be
...
```

**variability
model**

#2 Automated Product Derivation and Constraints Mining

Paper variants building and measurements

LONG_ACK	LONG_AFFILIATION	PARAGRAPH_ACK	PL_FOOTNOTE	VARY_LATEX	bref_size	cserver_size	vspace_bib	nbPages	
true	false	false	false	true	0.7	0.9	4.0	4	✓
false	false	false	false	true	0.8	0.6	2.2	4	✓
false	false	false	false	true	0.9	0.6	2.3	4	✓
true	true	true	true	true	0.7	0.8	1.1	4	✓
false	true	false	true	true	0.8	0.9	1.8	5	✗
false	true	false	false	true	0.7	0.8	2.8	5	✗
false	false	false	true	true	0.7	0.8	2.9	5	✗
false	true	false	false	true	0.9	0.7	4.9	4	✓
true	true	false	true	true	1.0	0.7	1.7	5	✗
false	false	false	true	true	1.0	0.6	1.8	5	✗
false	true	false	true	true	0.7	0.6	2.8	4	✓

Specialization of the variability model

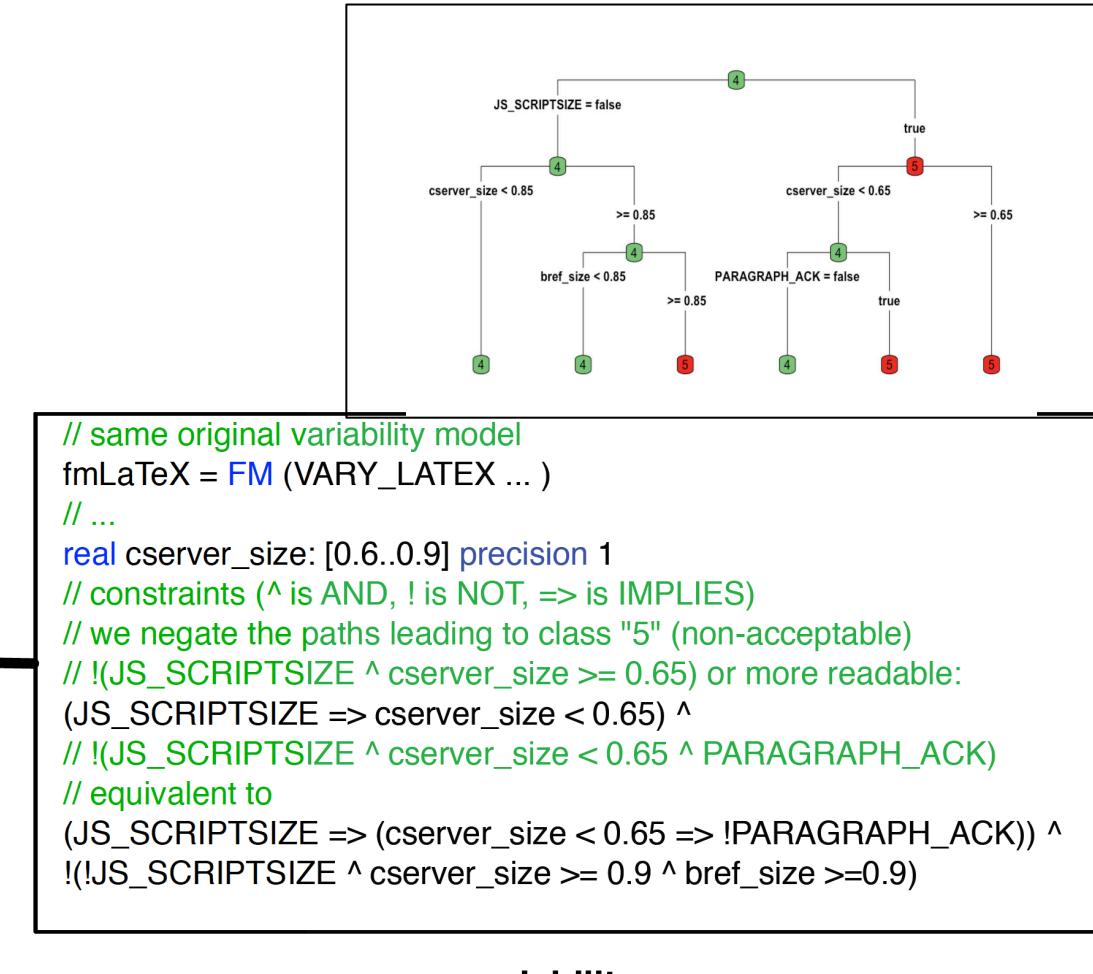
- VARY_LATEX
- ACK
- PARAGRAPH_ACK
- BOLD_ACK
- LONG_ACK
- JS_STYLE
- JS_FOOTNOTESIZE
- JS_TINY
- JS_SCRIPTSIZE
- PL_FOOTNOTE
- LONG_AFFILIATION
- EMAIL
- BIB
- BREF

▼ cserver_size

Min
0,6

Max
0,65

0,65



```

{{#if ACK}}
{{#if BOLD_ACK}}\textbf{Acknowledgements.}{#/if}}
{{#if PARAGRAPH_ACK}}\paragraph{Acknowledgements}{{/if}} We thank anonymous reviewers for their valuable feedbacks.
{{#if LONG_ACK}} We thank Pierre Laperdrix for the newspaper example. {{/if}}
% project fundings also
{{/if}}
%
\scriptsize
%\vspace*{-2mm}
\vspace*{-{{vspace_bib}}}mm
\bibliographystyle{abbrv}
\bibliography{DEModularity15}

```

Variability and LaTeX source files

(a) Variability annotations and excerpt of some possible paper variants

```

\lstdefinelanguage{JavaScript}{
    keywords={typeof, new, true, false, catch, function, return, null, catch, switch, var, if, in, while, do, else, case, break},
    keywordstyle=\color{blue}\bfseries,
    basicstyle=\ttfamily{{#if JS_SCRIPTSIZE}}\scriptsize{{/if}}{{#if JS_TINY}}\tiny{{/if}}{{#if JS_FOOTNOTESIZE}}\footnotesize{{/if}},
}

```

{{#if PL_FOOTNOTE}}\footnote{We are considering "product lines" in a broad sense,}

```

\begin{figure}
\centering
\includegraphics[width={{bref_size}}]\linewidth{figures/bref-generator.pdf}
\caption{\label{fig:generator}Video generator: modularity and variants}
\end{figure}

```

(b) Users can vary the font size of a code snippet, activate a footnote, vary the font size of a figure, etc.

Acknowledgements.

We thank anonymous reviewers for their valuable feedbacks. We thank Pierre Laperdrix for the newspaper example.

4. REFERENCES

Acknowledgements. We thank anonymous reviewers for their valuable feedbacks.

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4. REFERENCES

...

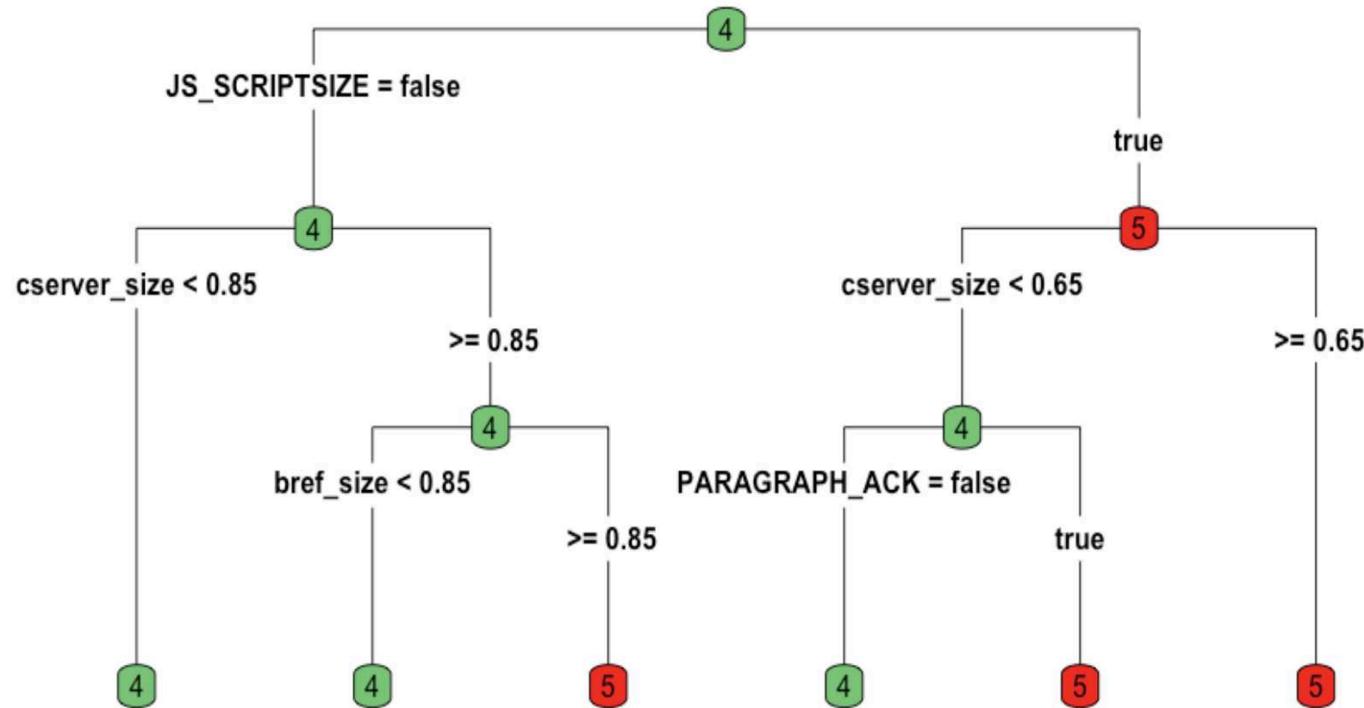
Acknowledgements.

We thank anonymous reviewers for their valuable feedbacks.

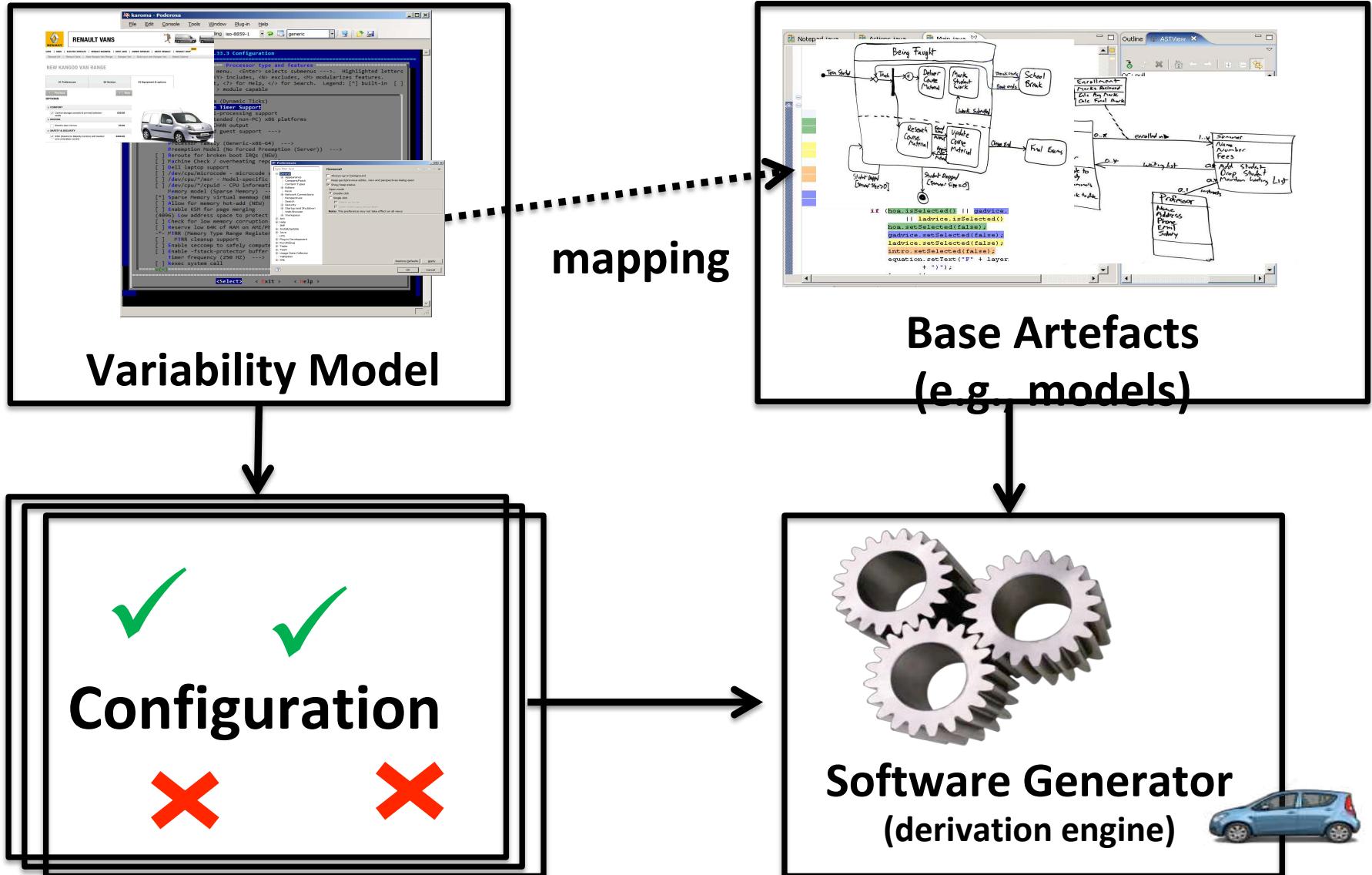
4. REFERENCES

Paper variants (PDF)

Classification tree



VaryLaTeX: an instance of a more general process



A wide-angle photograph of a massive parking lot packed with thousands of new vehicles, primarily sedans and SUVs, stretching across several city blocks. The cars are arranged in long, dense rows, creating a repetitive pattern. In the foreground, there are several white delivery vans and small trucks. The background shows a clear sky and some industrial structures, suggesting a port or a large manufacturing facility.

Product Lines

(Software) Product Lines



01011011
11011110
00110110
110011101
100011111
10100110
10001010
10101011
00001110
11010101
11110110
01100100
01010101
11010110
10101101

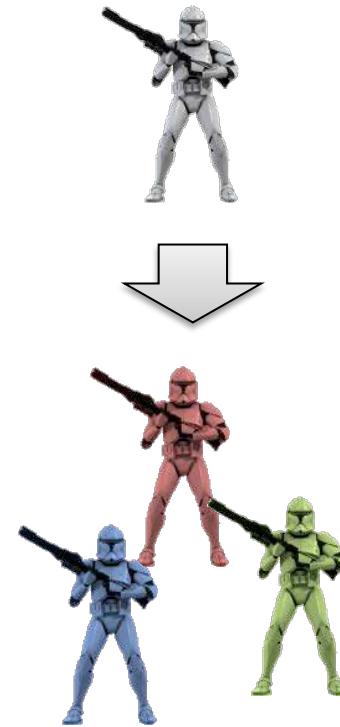


The three ways to build a (software) product

Independently



„Clone & Own“



„Shared“ (reusable) Assets



(credits: Thorsten Berger's slide)

The three ways to build a (software) product

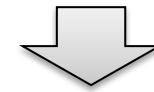
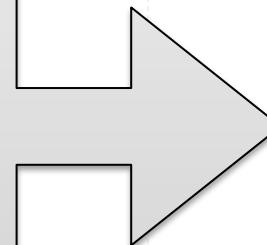
Independently

„Clone & Own“

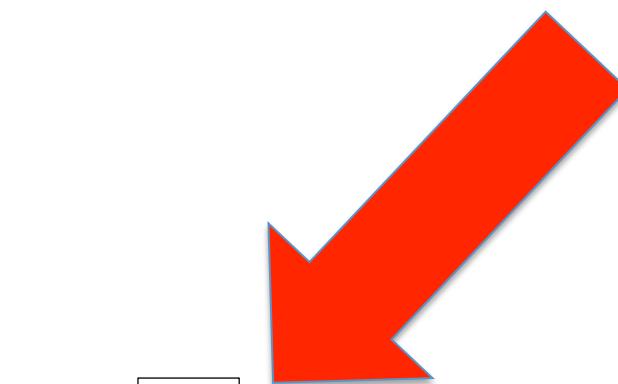
„Shared“ (reusable) Assets

Software Product Lines

- Product Configuration
- Variability Modeling
- Components
- Domain-specific Languages
- Generators
- Preprocessors
- Design Patterns
- ...

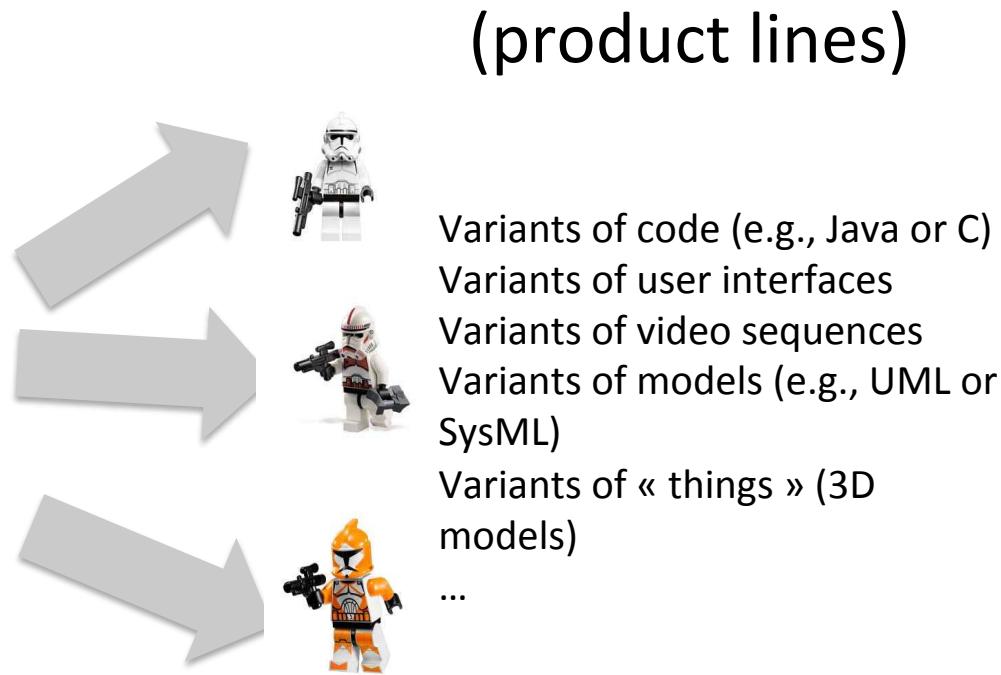


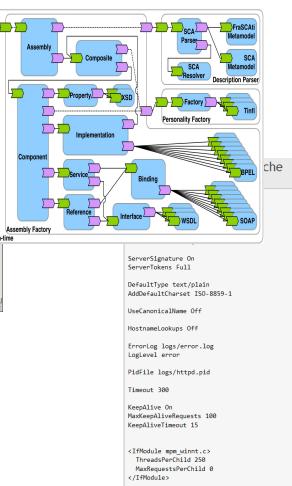
Modeling and Reverse Engineering Variability



Feature models
or Product Matrices

Product	License	Price	Language Support	Language	WYSIWIG
W1	Commercial	10	Yes	Java	Yes
W2	NoLimit	20	No		Yes
W3	NoLimit	10	No		Yes
W4	GPL	0	Yes	Python	Yes
W5	GPL	0	Yes		Yes
W6	GPL	10	Yes	Perl	Yes
W7	GPL	0	Yes	PHP	No
W8	GPL	10	Yes		Yes





RENAULT VANS

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

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

NEW KANGOO VAN RANGE

01 Preferences 02 Version 03 Equipment & options

OPTIONS

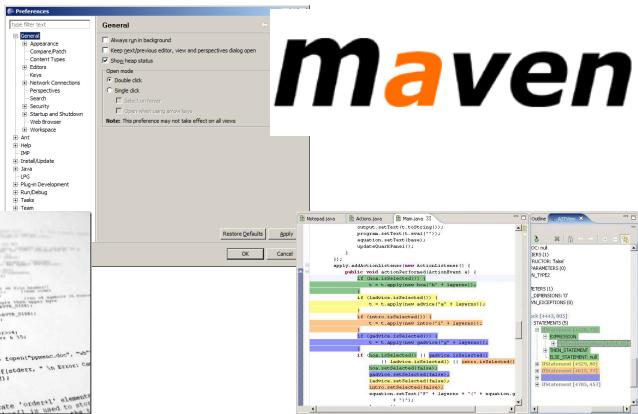
> COMFORT
 Centre storage console & armrest between seats £29.00
 Electric door mirrors £3.00
 ESC (Electronic Stability Control) with traction and understeer control £200.00

> DRIVING

> SAFETY & SECURITY

Vehicle

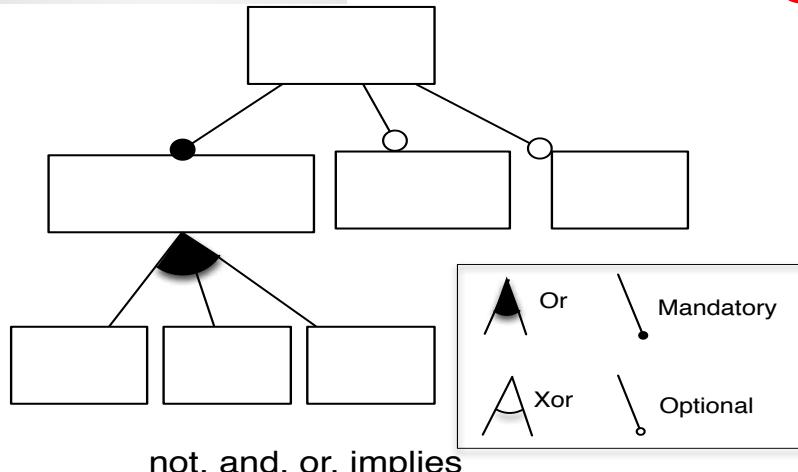
A small white Renault Kangoo van.



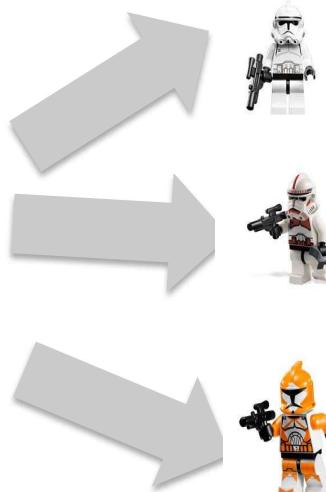
maven

Mining/Extracting Encoding/Formalizing Synthesising

FAMiliAR

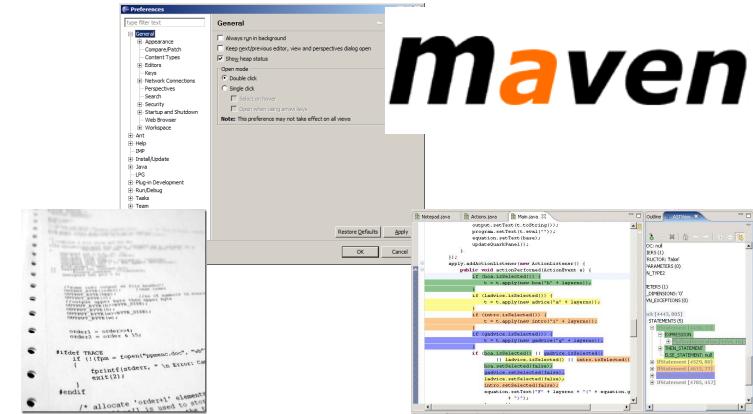
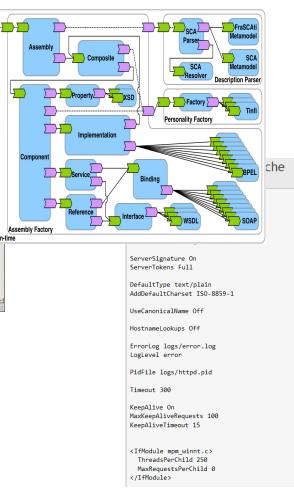
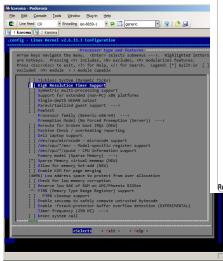


Variability Models (feature models)



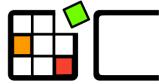
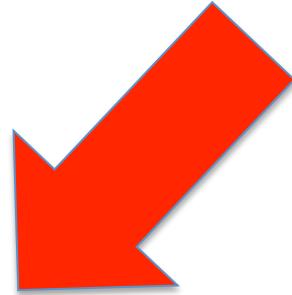
Variants of code (e.g., Java or C)
 Variants of user interfaces
 Variants of video sequences
 Variants of models (e.g., UML or SysML)
 Variants of « things » (3D models)

...



maven

Mining/Extracting Encoding/Formalizing Synthesising

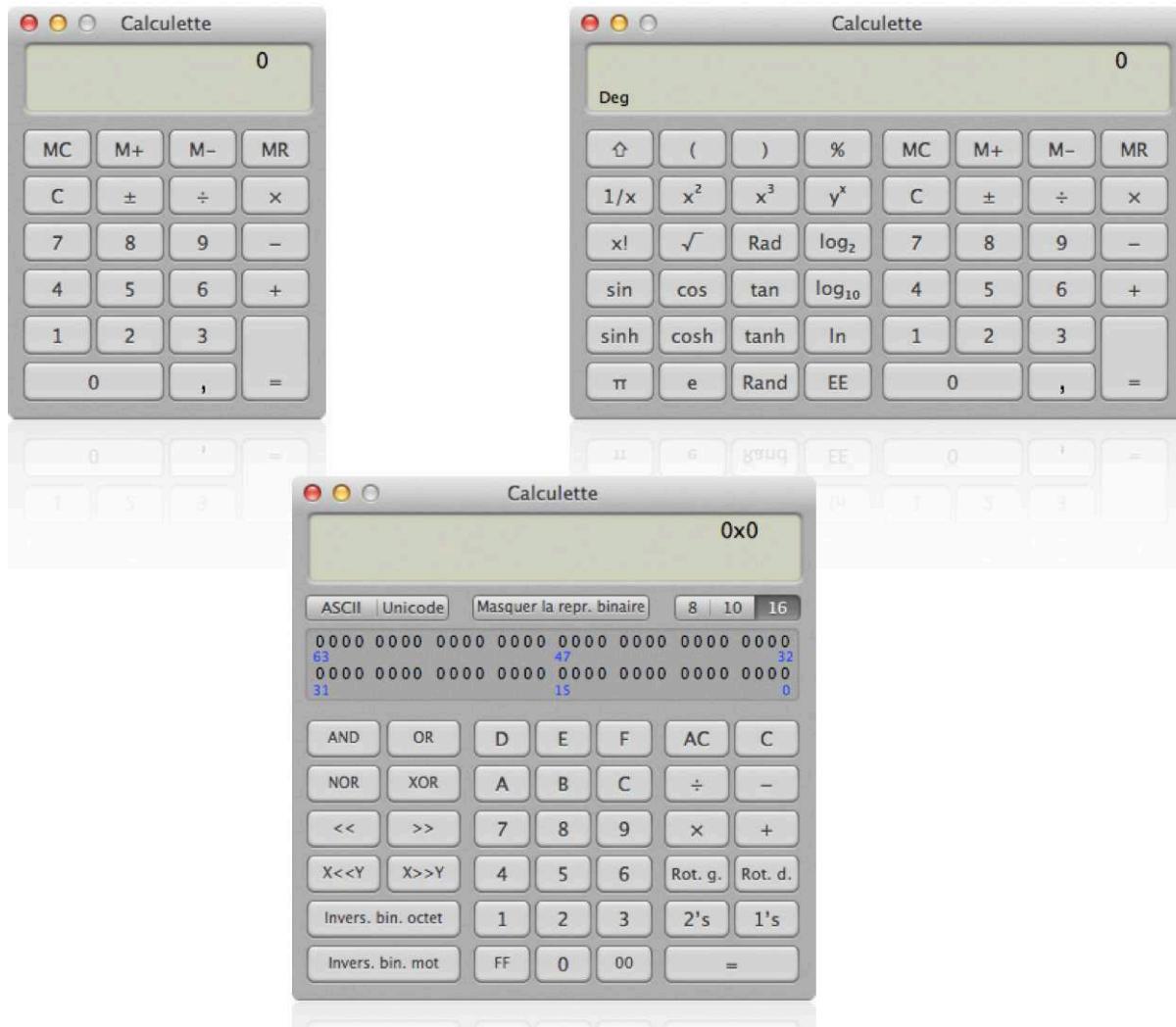


OpenCompare

Product ▾	License	Price	Language Support	Language	WYSIWIG
W1	Commercial	10	Yes	Java	Yes
W2	NoLimit	20	No		Yes
W3	NoLimit	10	No		Yes
W4	GPL	0	Yes	Python	Yes
W5	GPL	0	Yes	Perl	Yes
W6	GPL	10	Yes	Perl	Yes
W7	GPL	0	Yes	PHP	No
W8	GPL	10	Yes	PHP	Yes

Variability and Software Product Lines

Perhaps, you ignore the names of something omnipresent in numerous contexts



« 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

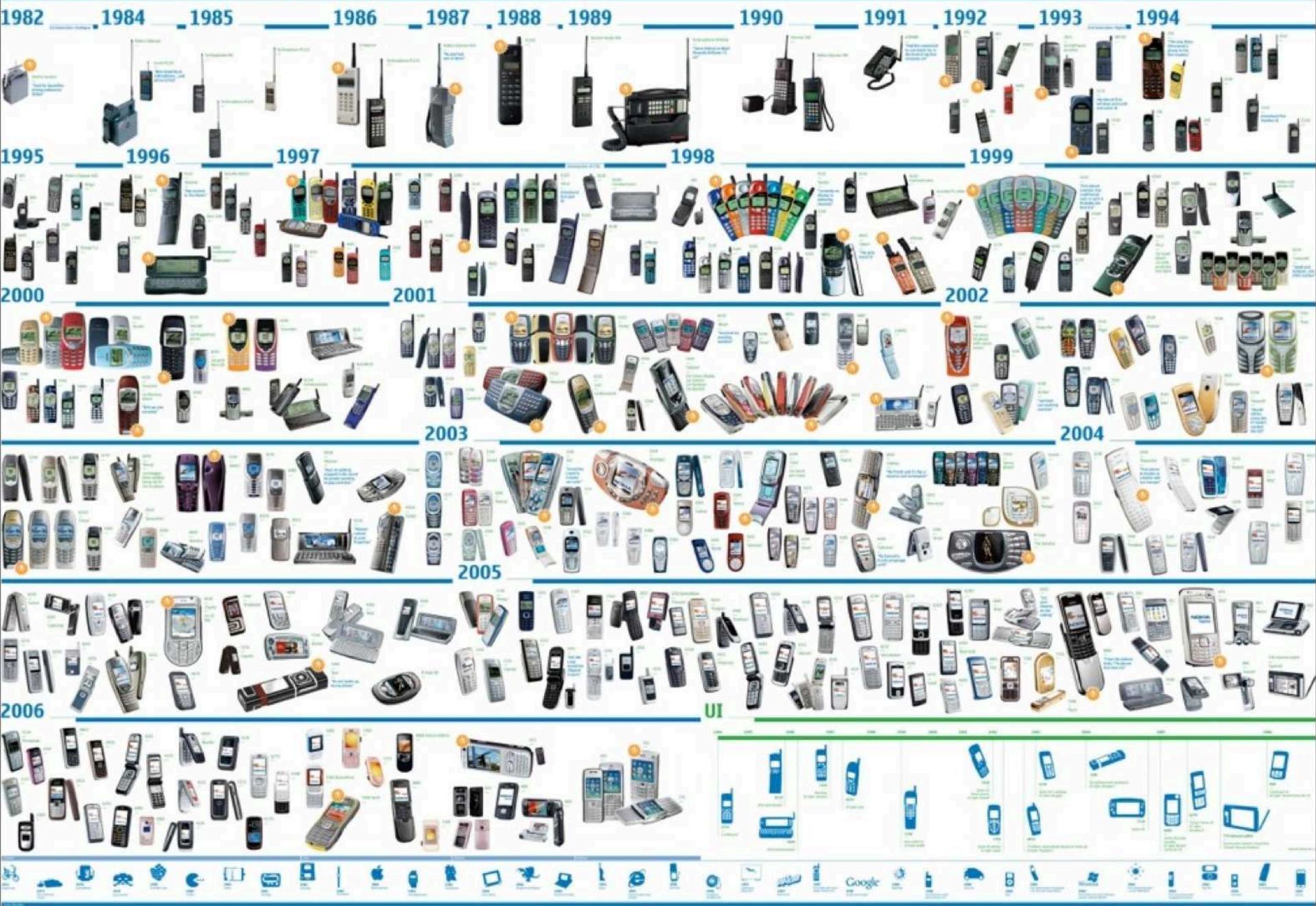
David L. Parnas — “On the design and development of program families” in Transactions on Software Engineering, SE-2(1):1–9, 1976

Variability

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

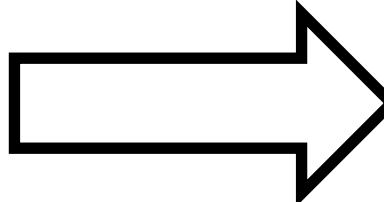
Mikael Svahnberg, Jilles van Gurp, and Jan Bosch (2005)







Software-intensive systems



come in many variants



RENAULT VANS



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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
---	---------



“Reverse Engineering Web Configurators” Ebrahim Khalil Abbasi, Mathieu Acher, Patrick Heymans, and Anthony Cleve. In 17th European Conference on Software Maintenance and Reengineering (CSMR'14)

LE PLIAGE PERSONNALISÉ

MODÈLES

COULEUR
RECTO

COULEUR
VERSO

BOUCLERIE

RESET



LE PLIAGE CUIR

LE PLIAGE TOILE



VOTRE PERSONNALISATION

Porte-monnaie Toile : 9 x 7 x 5 cm
Couleur recto : Garance
Couleur verso : Malabar
Bouclerie : Bronze

35,00 € AJOUTER AU PANIER

Infos Partager J'aime

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
Utilities
Video
Word Processing
 GLOBAL PAGES >>
NEWS ARCHIVE >>
DFTPEDIA REVIEWS >>
MEET THE EDITORS >>

Power Matte 2.0.1.3 update



Adobe After Effects plugin that can extract any object 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



Gridus 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

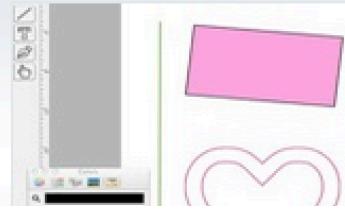


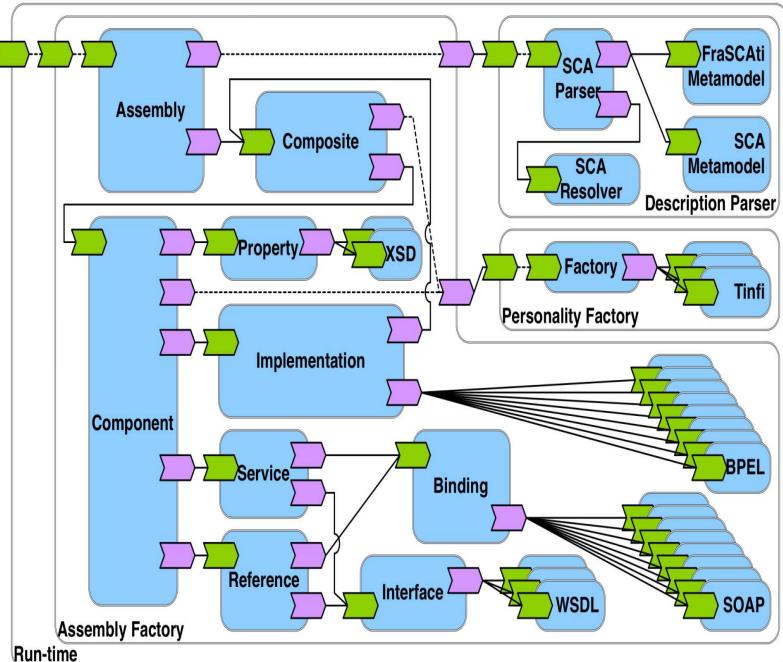
FashionLab Studio 1.1 update



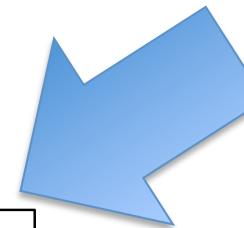
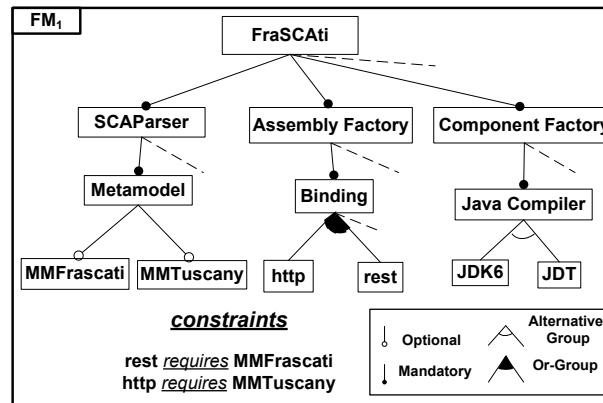
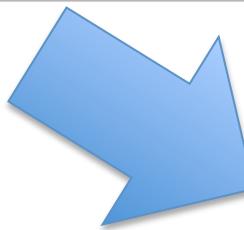
Makes it easy to design your own T-shirt using a Mac
[\[read more >\]](#)

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



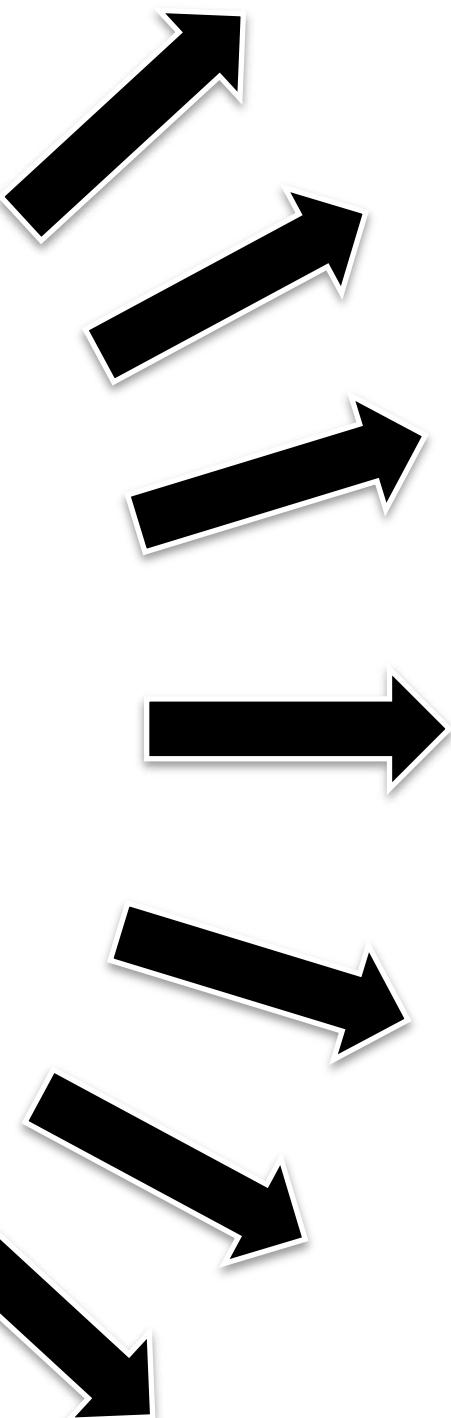


maven



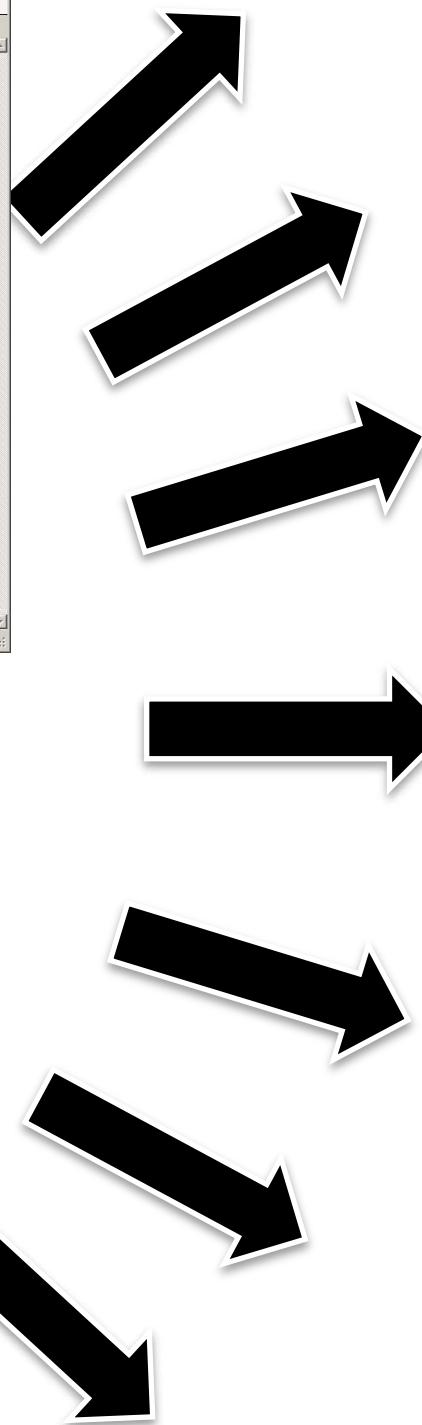
Variability Model

Printer Firmware



Linux Kernel

```
Line feed: CR 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, <> 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 [ ] Symmetric Multi-processing support [ ] Support for extended (non-PC) x86 platforms [ ] Single-depth KCHAN output [ ] Paravirtualized guest support ... Memtest [ ] Processor family (Generic-x86-64) ---> [ ] Preemption Model (No Forced Preemption (Server)) ---> [ ] Renote for broken boot IRQ (NEW) [ ] Machine Check / overheating reporting [ ] Dell laptop support [ ] /dev/cpu/microcode - microcode support [ ] /dev/cpu/*msr - Model-specific register support [ ] /dev/cpu/*cpuid - CPU information support [ ] Memory model (Sparse Memory) ---> [*] Sparse Memory Virtual memmap (NEW) [ ] Allow for memory hot-add (NEW) [ ] Enable KSM for page merging (4096) Low address space to protect from user allocation [ ] Check for low memory corruption [ ] Reserve low 64M of RAM on AMI/Phoenix BIOSes [ ] MTTR (Memory Type Range Register) support [ ] MTTR cleanup support [ ] Enable seccomp to safely compute untrusted bytecode [ ] Enable -fstack-protector buffer overflow detection (EXPERIMENTAL) [ ] Timer frequency (250 Hz) ---> [ ] kexec system call <(<> Select> < Exit > < Help >
```



Brand	Model name	Sensor size	Effective megapixels	Lens mount	Viewfinder type	Viewfinder coverage (% of the frame)	Metering zones	Focus points	Lowest ISO	Highest ISO	DxOMark sensor score	DxO ISO performance ^[1]	
Canon	1D X	Full frame	18.1	EF	Pentaprism	100	252	61	50	204800	82	2786	
Canon	1Ds Mark III	Full frame	21.1				63	45	50	3200	80	1663	
Canon	1D Mark IV	APS-H	16.1				63	45	50	102400	74	1320	
Canon	5D Mark III	Full frame	22.3				63	61	50	102400	81	2293	
Canon	5D Mark II	Full frame	21.1				35	9	50	25600	79	1815	
Canon	6D	Full frame	20.2				63	11	100	102400	82	2340	
Canon	7D	APS-C	18.0				63	19	100	12800	66	854	
Canon	70D	APS-C	20.2				63	19	100	25600	68	926	
Canon	60D	APS-C	18.0				63	9	100	12800	66	813	
Canon	50D	APS-C	15.1		EF, EF-S	Pentaprism	95	35	9	100	12800	63	696
Canon	40D	APS-C	10.1		EF, EF-S	Pentaprism	95	35	9	100	3200	64	703
Canon	30D	APS-C	8.2		EF, EF-S	Pentaprism	95	35	9	100	3200	59	736
Canon	20D	APS-C	8.2		EF, EF-S	Pentaprism	95	35	9	100	3200	62	721



Guillaume Bécan, Nicolas Sannier, Mathieu Acher, Olivier Barais, Arnaud Blouin, and Benoit Baudry.
 Automating the Formalization of Product Comparison Matrices (2014). In 29th IEEE/ACM International Conference on Automated Software Engineering (ASE'14)



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

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

```
[1/15] [P] Generating application configuration  
[2/15] [P] Generating application entities  
[3/15] [P] Generating application services  
[4/15] [P] Generating application controllers  
[5/15] [P] Generating application entities  
[6/15] [P] Generating application services  
[7/15] [P] Generating application controllers  
[8/15] [P] Generating application entities  
[9/15] [P] Generating application services  
[10/15] [P] Generating application controllers  
[11/15] [P] Generating application entities  
[12/15] [P] Generating application services  
[13/15] [P] Generating application controllers  
[14/15] [P] Generating application entities  
[15/15] [P] Generating application services
```

Welcome to the JHipster Generator v2.17.0

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

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

184 lines (165 sloc) | 9.69 KB

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

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

Variability

```

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();
    }
}

```

```

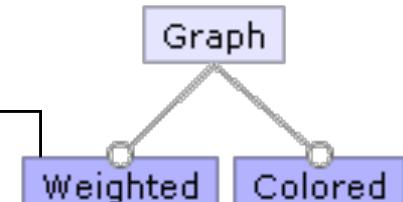
class Color {
    static void setDisplayColor(Color c) { ... }
}

```

```

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

```



Mining Features from the Object-Oriented Source Code of Software Variants by Combining Lexical and Structural Similarity

R. AL-msie'deen, A.-D. Seriai, M. Huchard

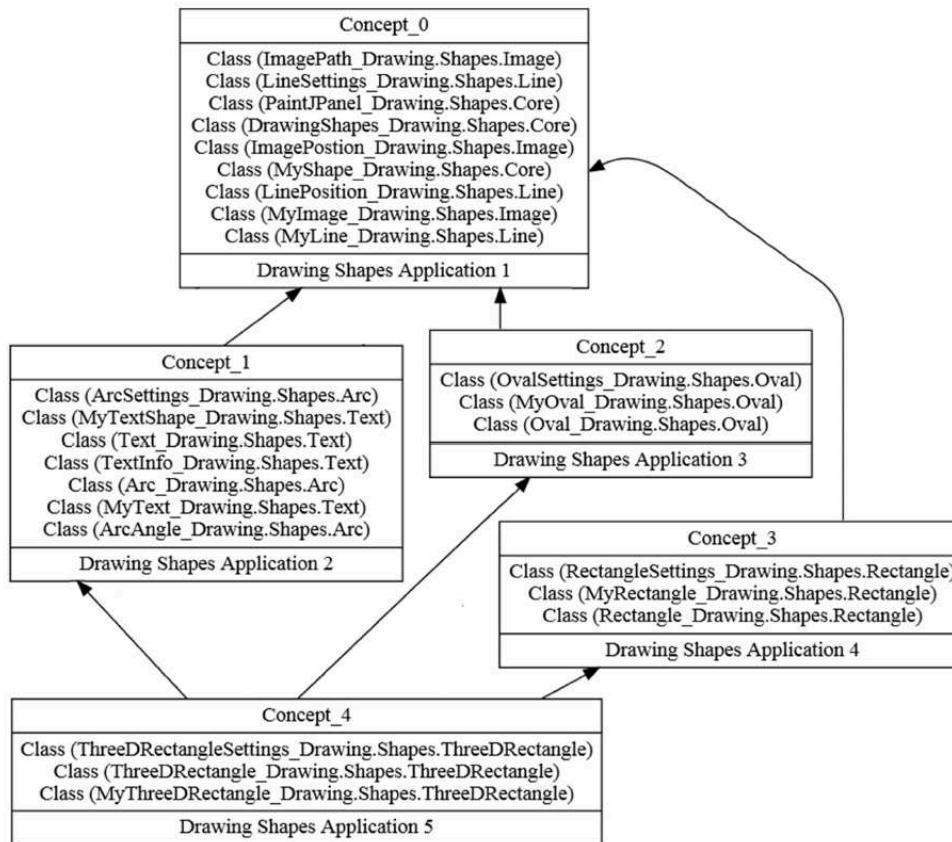
LIRMM / CNRS & Montpellier 2 University, Montpellier, France

Al-msiedee, Abdelhak.Seriai, huchard@lirmm.fr

C. Urtado and S. Vauttier

LGI2P / Ecole des Mines d'Alès, Nîmes, France

Christelle.Urtado, Sylvain.Vauttier@mines-ales.fr



	Class (ArcSettings_Drawing.Shapes.Arc)	Class (Arc_Drawing.Shapes.Arc)	Class (ArcAngle_Drawing.Shapes.Arc)	Class (MyTextShape_Drawing.Shapes.Text)	Class (Text_Drawing.Shapes.Text)	Class (TextInfo_Drawing.Shapes.Text)	Class (MyText_Drawing.Shapes.Text)
Class (ArcSettings_Drawing.Shapes.Arc)	X	X	X				
Class (Arc_Drawing.Shapes.Arc)	X	X	X				
Class (ArcAngle_Drawing.Shapes.Arc)	X	X	X				
Class (MyTextShape_Drawing.Shapes.Text)				X	X	X	X
Class (Text_Drawing.Shapes.Text)				X	X	X	X
Class (TextInfo_Drawing.Shapes.Text)				X	X	X	X
Class (MyText_Drawing.Shapes.Text)				X	X	X	X

Video Encoder



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



(a) Variant #1 of video sequence



(b) Variant #2 of video sequence



(c) Variant #3 of video sequence



(d) Variant #4 of video sequence

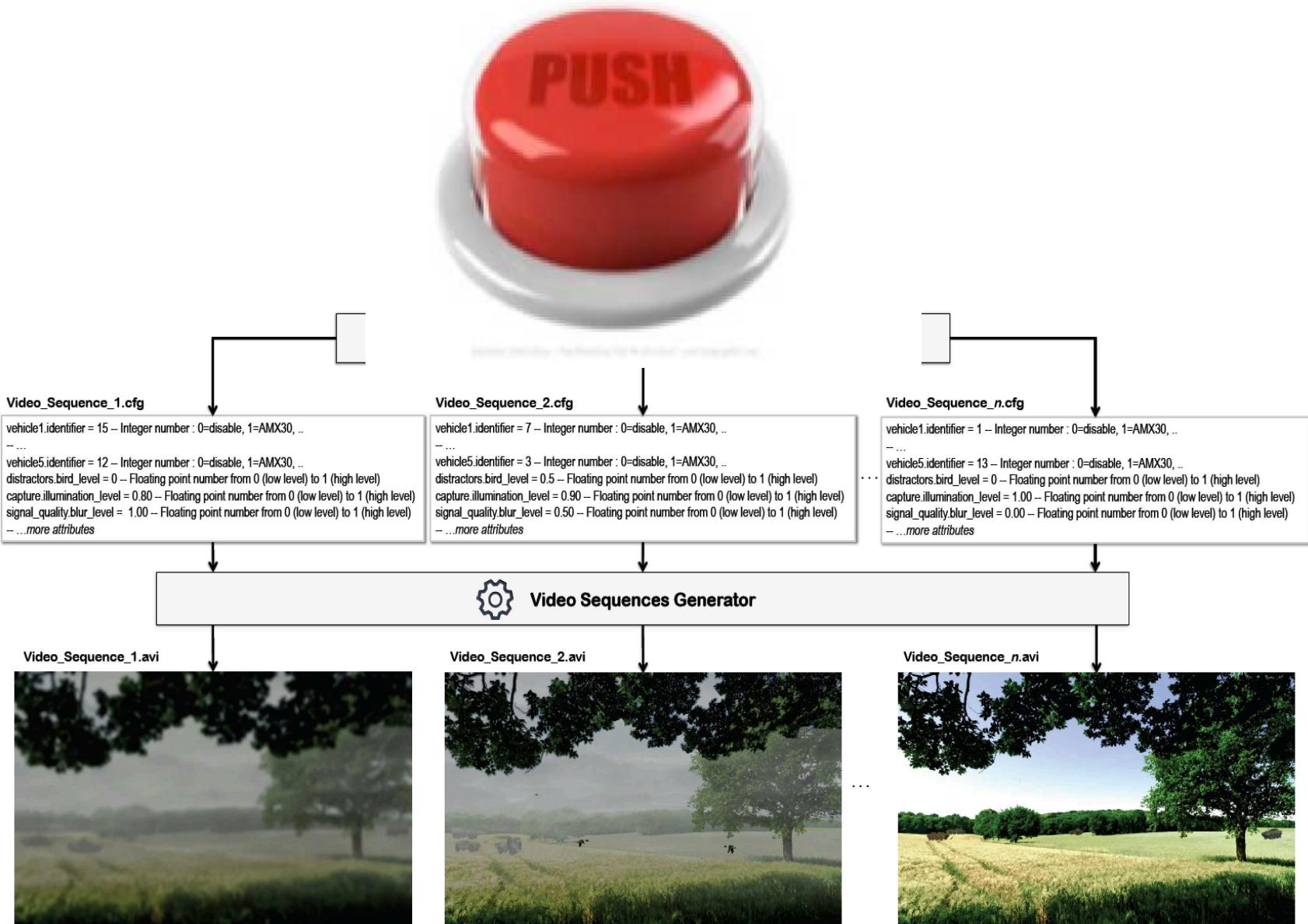


(e) Variant #5 of video sequence



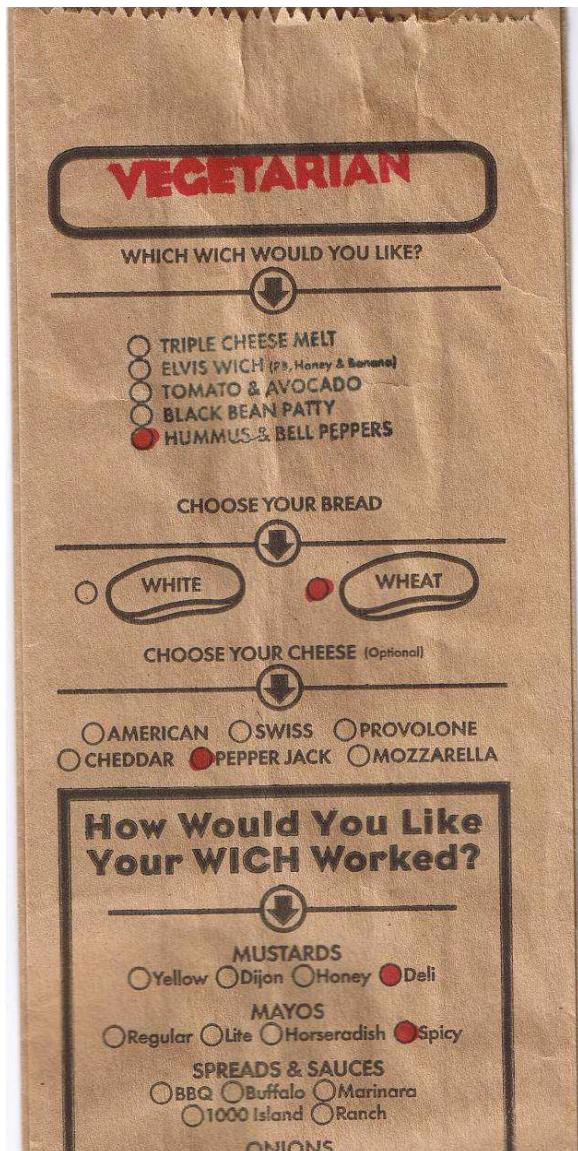
(f) Variant #6 of video sequence

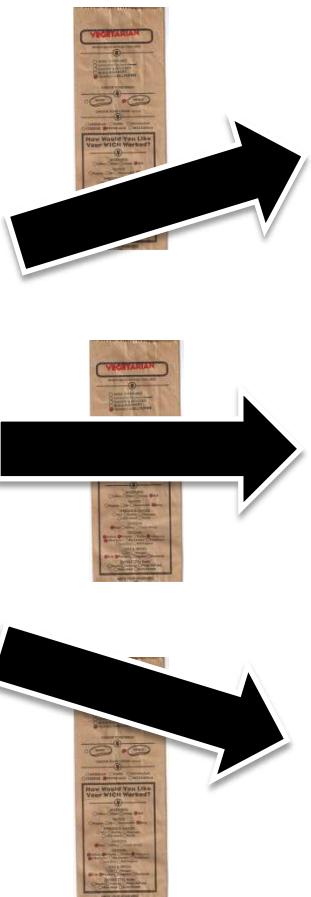
Figure 1: Six variants of video sequences synthesized with ViViD



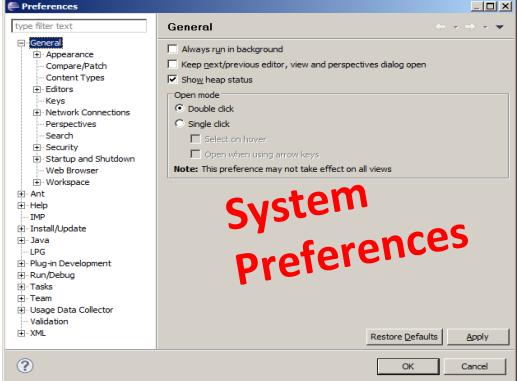
(credits: Christian Kaestner's slide)

Food? Product lines!

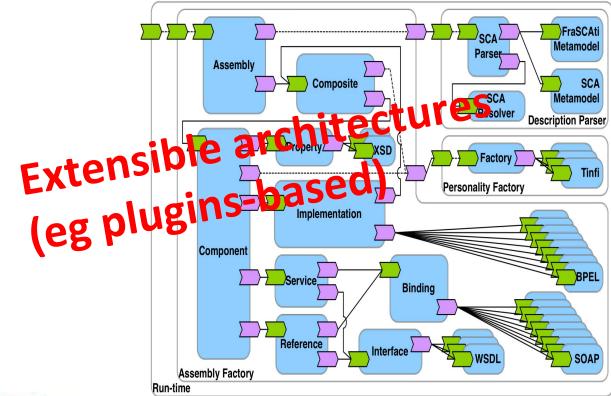




Configurators



System Preferences



Extensible architectures
(eg plugins-based)



Comparison of *

Product Lines and Variability



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

DenyType text/plain
AddDefaultCharset ISO-8859-1

UseCanonicalName Off

HostnameLookups Off

ErrorLog logs/error.log
LogLevel error

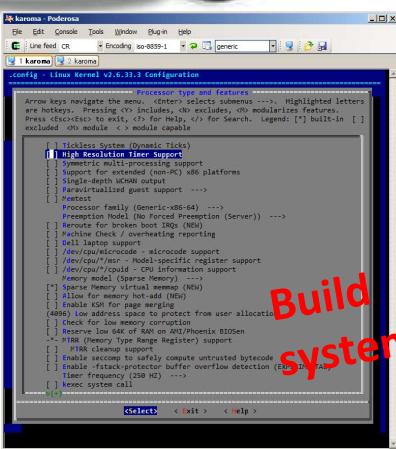
PidFile logs/httpd.pid

Timeout 300

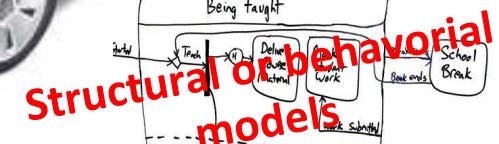
KeepAlive On
MaxKeepAliveRequests 100
KeepAliveTimeout 15

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

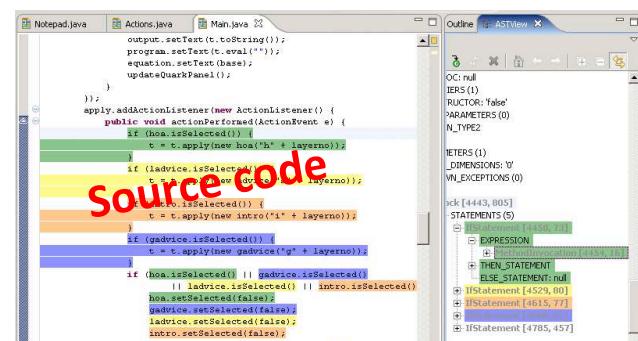
Configuration files



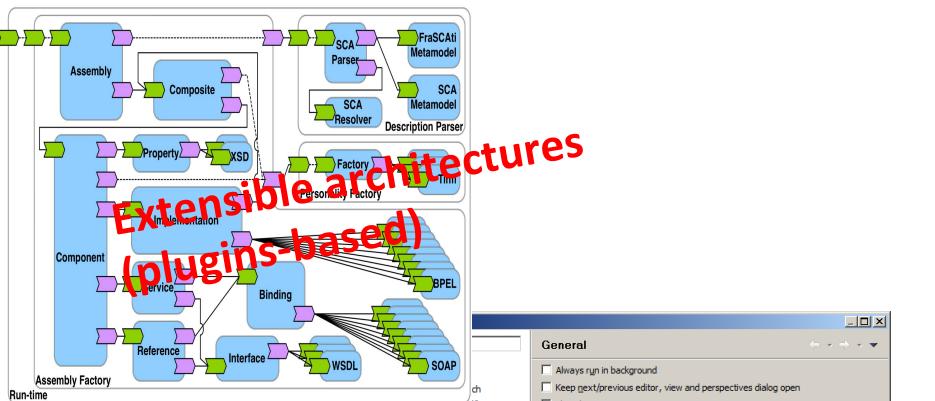
Build systems



Structural or behavioral models



Source code



httpd.conf -- win32 App 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
```

Configuration files

```
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>
```



NEW KANGOO VAN RANGE



OPTIONS

> COMFORT
 Storage, table & armrests
 DRIVING
 Electronic stability control (ESC) with traction and understeer control

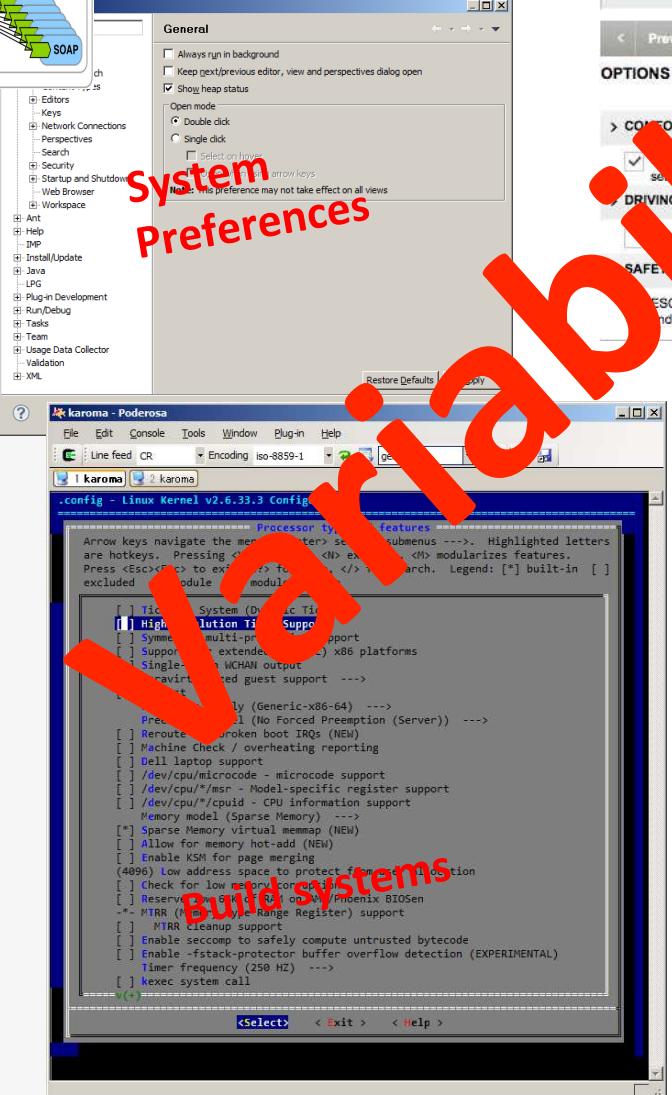
£50.00

Compare Adobe Creative Suite 4 editions

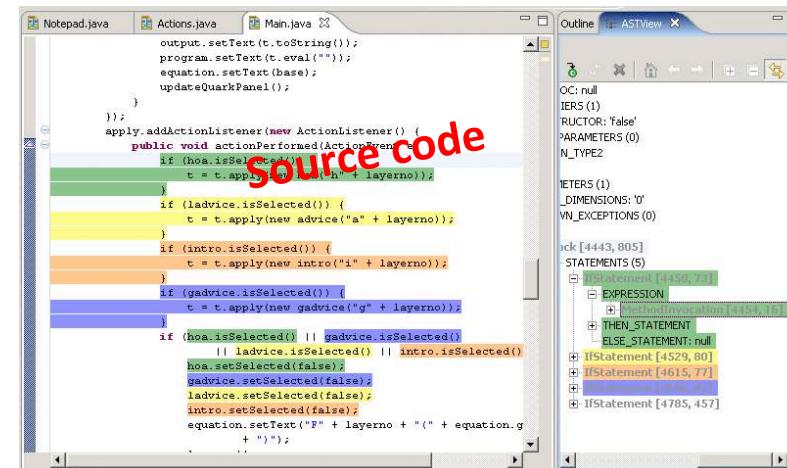


Check the box beside the products you want which edition they're in.

COMPONENTS	Design Premium	Design Standard	Web Premium	Web Standard	Production Premium	Production Standard	Master Collection
Adobe InDesign CS4	•						
Adobe Photoshop CS4 Extended	•						
Adobe Photoshop CS4		•					
Adobe Illustrator CS4		•					
Adobe Acrobat CS4		•					
Adobe Dreamweaver CS4		•					
Adobe Fireworks CS4	•						
Adobe Contribute CS4		•					
Adobe After Effects CS4		•					
Adobe Premiere Pro CS4*		•					
Adobe Soundbooth CS4			•				
Adobe OnLocation™ CS4*			•				
Adobe Encore® CS4			•				
SHARED FEATURES, SERVICES, AND APPLICATIONS							
Adobe Bridge CS4	•	•	•	•	•	•	•
Adobe Device Central CS4		•	•	•	•	•	•
Adobe Dynamic Link			•	•	•	•	•
Adobe Version Cue® CS4	•						



Build systems



Source code

Quizz Time

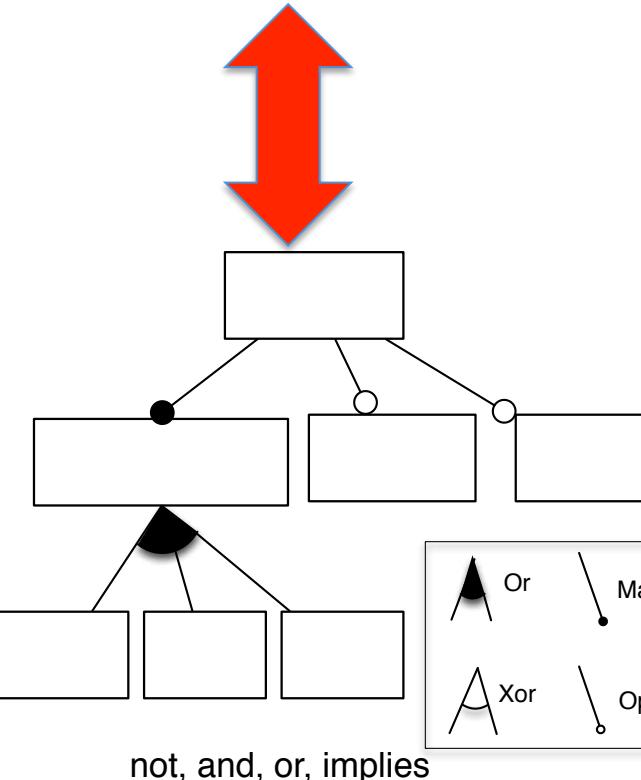
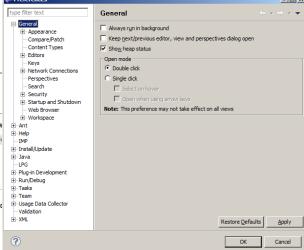
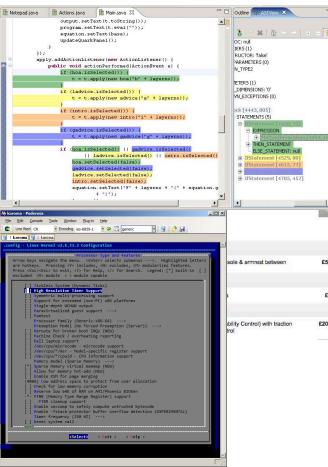
Give three examples of software product lines (also called configurable systems or variability-intensive systems)

Software is eating the world (any company will be a software company)

If you have the super-power to
“**vary**” (e.g., for delivering customized
solutions to customers; or for
engineering customized solutions for
addressing your specific problems)

Then you will rule the world





Variants of code (e.g., Java ou C)
 Variants of user interfaces
 Variants of video sequences
 Variants of models (e.g., UML or SysML)
 Variants of « things » (3D models)

...



Variability Models

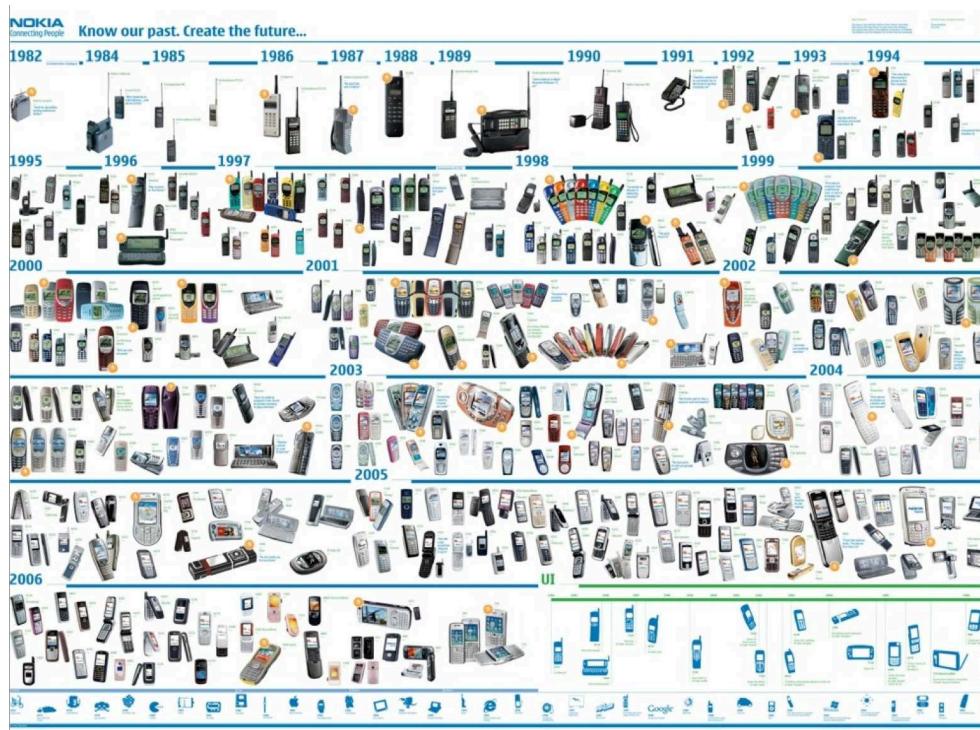
(feature models)

Variability: two definitions

- “the **ability** of a software system or artifact to be efficiently extended, changed, customized or configured for use in a particular context” (Svahnberg et al. 2005)
 - software/**customization** perspective
- “an assumption about how members of a family may **differ** from each other” (Weiss and Lai 1999)
 - more related to the notions of **domain** and **commonality**

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

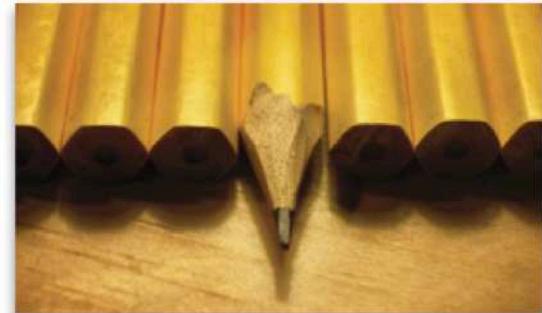
Improve product reliability



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 large, intricate 3D white maze is set against a light gray background. The maze is composed of many interconnected paths and dead ends, creating a sense of complexity and depth. The perspective is from above, looking down into the various levels and recesses of the labyrinth.

Variability = Complexity

(credits: Christian Kaestner's slide)

33 features

optional, independent



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



Software product line and Variability engineering

Basic techniques

What is new?

Family vs single systems

Focus on reuse

Domain engineering

Factoring out commonality

Managing variability

« variability »

Is it really new?

Intentional Code Cloning

~ Copy & Paste

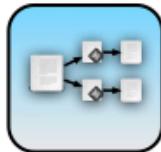
Code Cloning (example, Linux driver)

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;  
}  
.....
```

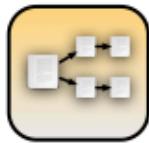


Replicate & Specialize

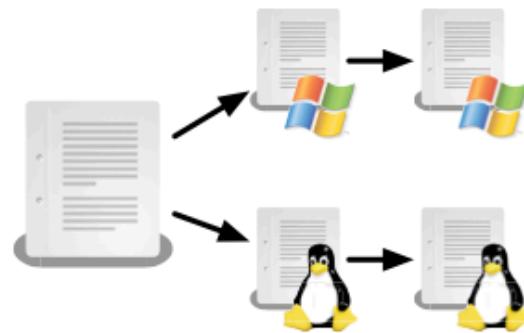


Clone to reuse and adapt existing solutions

- + 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

“Cloning Considered Harmful” Considered Harmful

Cory Kapser and Michael W. Godfrey
Software Architecture Group (SWAG)

David R. Cheriton School of Computer Science, University of Waterloo
{cjkapser, migod}@uwaterloo.ca

"Cloning considered harmful" considered harmful: patterns of cloning in software

Authors: Cory J. Kapser

Software Architecture Group (SWAG) David R. Cheriton
School of Computer Science, University of Waterloo,
Waterloo, Canada

Michael W. Godfrey

Software Architecture Group (SWAG) David R. Cheriton
School of Computer Science, University of Waterloo,
Waterloo, Canada



2008 Article

Published in:

- Journal

Empirical Software Engineering archive

Volume 13 Issue 6, December 2008

Pages 645 - 692

Kluwer Academic Publishers Hingham, MA, USA

table of contents doi>10.1007/s10664-008-9076-6

Bibliometrics

- Downloads (6 Weeks): n/a
- Downloads (12 Months): n/a
- Downloads (cumulative): n/a
- Citation Count: 48

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     }
}
```

Command Line Options



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

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
```

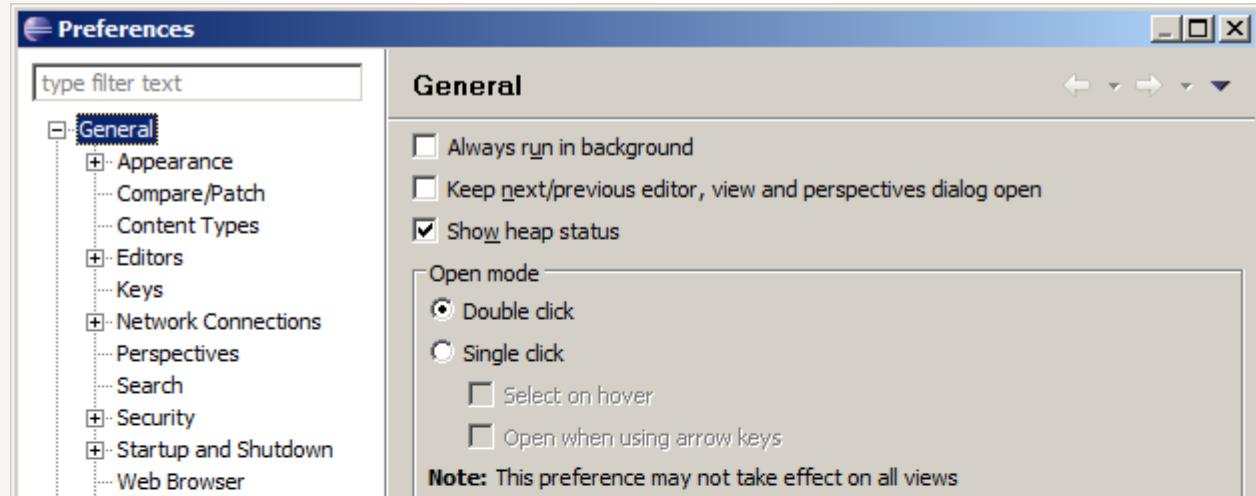
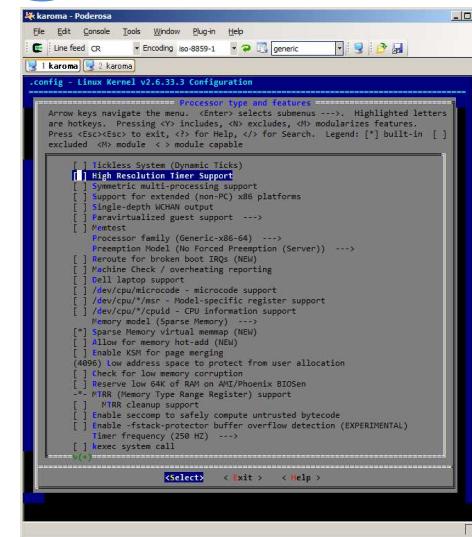
```
HostnameLookups Off
```

```
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
```

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

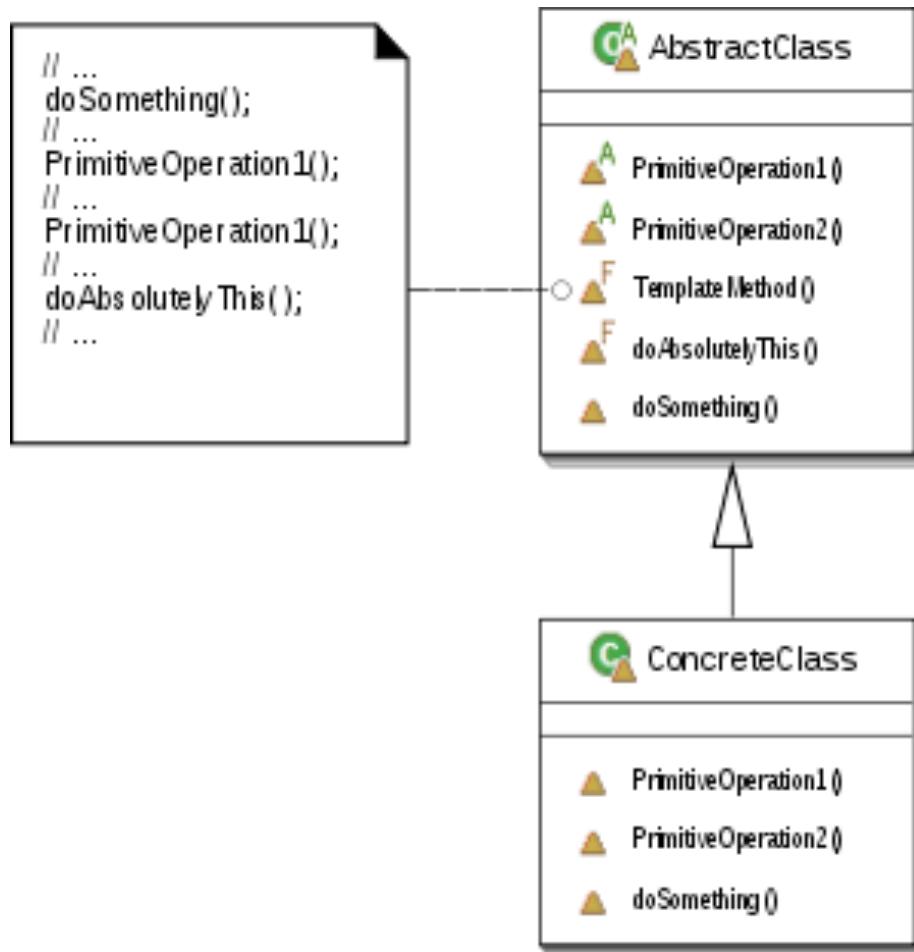
Factory

Strategy

Decorator

....

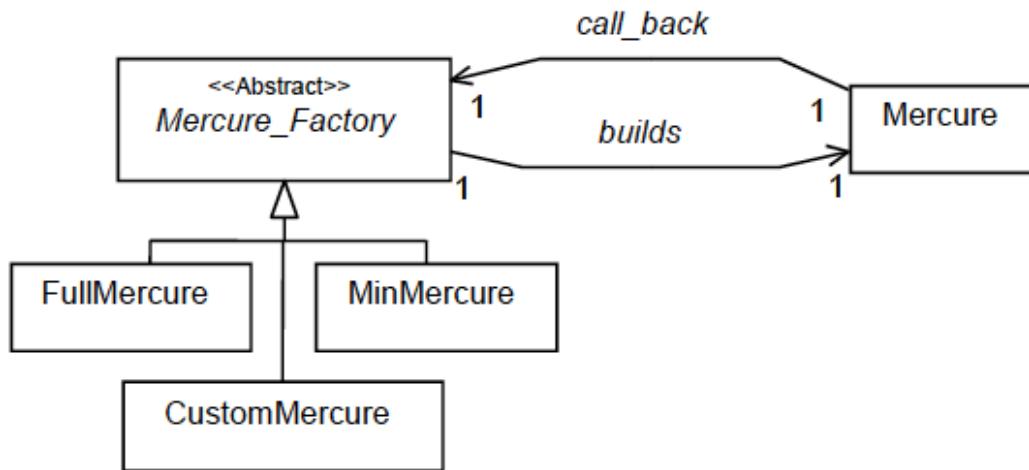
Template Method



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

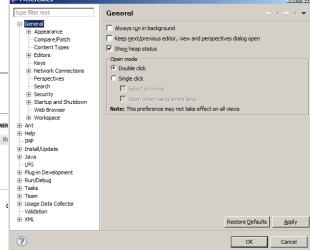
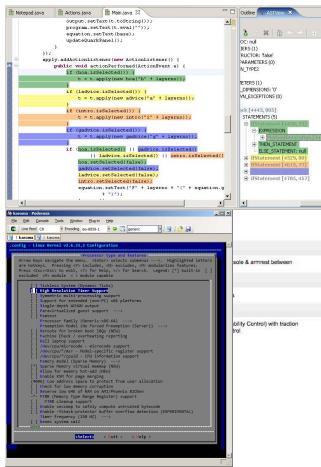
Plugin-based systems

(Active) Annotations

can have parameters

Metamodeling and Domain-Specific Languages

Variability (general approach)



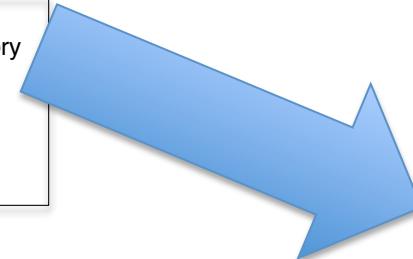
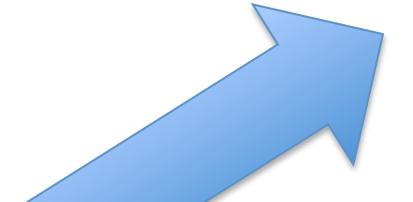
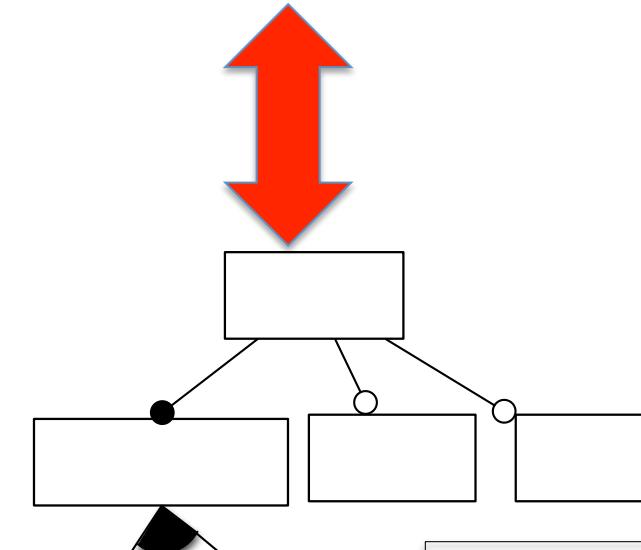
Variants of code (e.g., Java ou C)

Variants of user interfaces

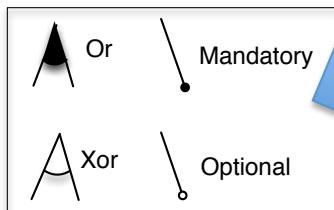
Variants of video sequences

Variants of models (e.g., UML or SysML)

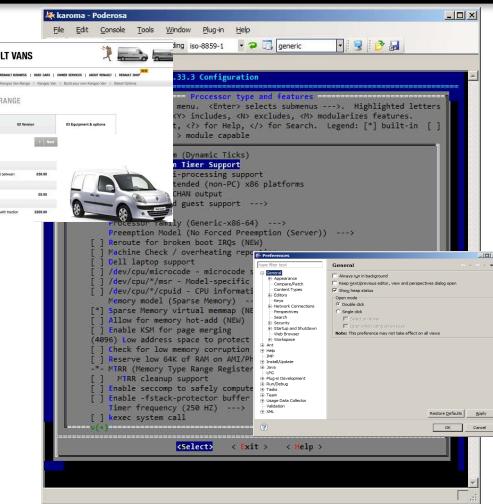
...



not, and, or, implies

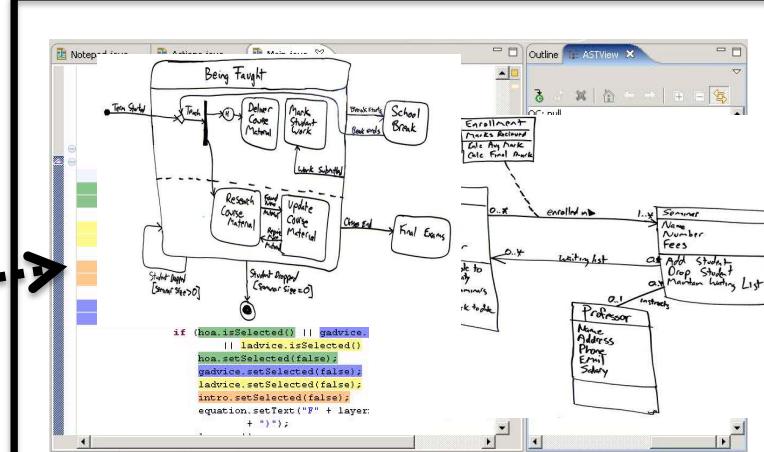


Variability Models (feature models)



Variability Model

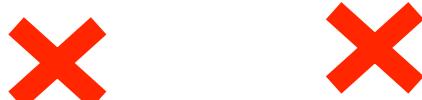
mapping



Base Artefacts (e.g.,
models)

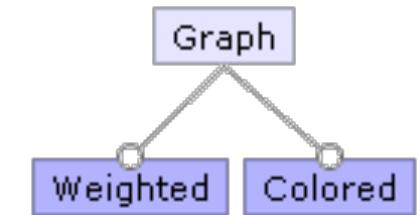


Configuration



Software Generator
(derivation engine)





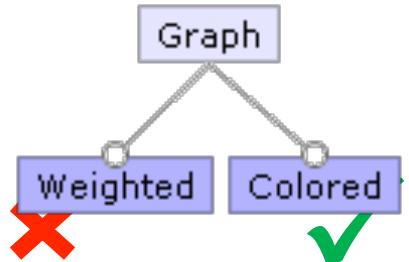
Variability Model

mapping

```

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();
        }
    }
}
  
```

Base Artefacts



```

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();
        }
    }
}
  
```

Software Generator (derivation engine)

Mapping: an example

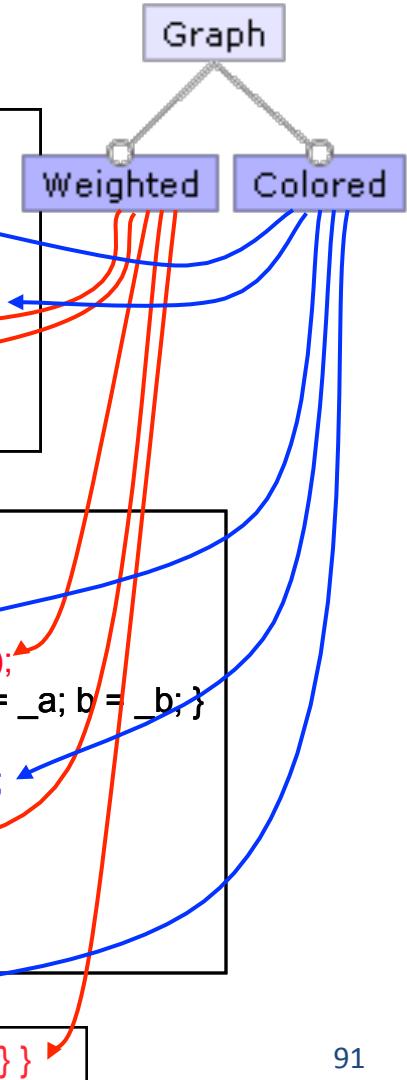
```
class Graph {  
    Vector nv = new Vector(); Vector ev = new Vector();  
    Edge add(Node n, Node m) {  
        Edge e = new Edge(n, m);  
        nv.add(n); nv.add(m); ev.add(e);  
        e.weight = new Weight();  
        return e;  
    }  
    Edge add(Node n, Node m, Weight w)  
    Edge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

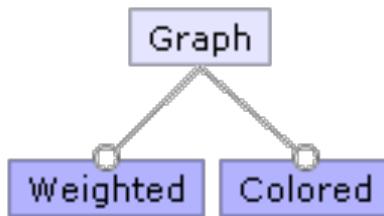
```
class Node {  
    int id = 0;  
    Color color = new Color();  
    void print() {  
        Color.setDisplayColor(color);  
        System.out.print(id);  
    }  
}
```

```
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]*/
    }
}

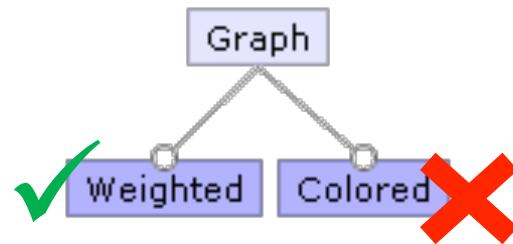
/*if[COLOR]*/
class Color {
    static void setDisplayColor(Color c) { ... }
}
/*end[COLOR]*/

```

```

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();
        }
    }
}
    
```

```

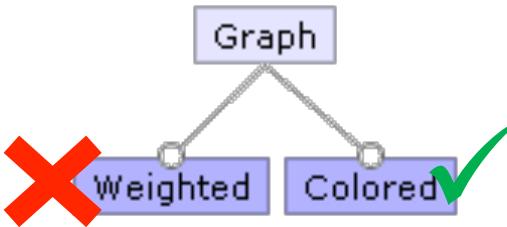
class Edge {
    Node a, b;
    Weight weight;
    Edge(Node _a, Node _b) { a = _a; b = _b; }
    void print() {
        a.print(); b.print();
        weight.print();
    }
}
    
```

```

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);
    }
}

```

Kästner “Virtual Separation of Concerns: Toward Preprocessors 2.0”

```
1 class Add extends Expr { //yellow
2     Expr left, right;
3     Add(Expr l, Expr r)
4         { left=l; right=r; }
5     double eval() { //red
6         return left.eval() +
7             right.eval();
8     }
9     void print() { //blue
10        left.print();
11        System.out.print("+");
12        right.print();
13    }
14 }
```

Features: ADD, EVAL, PRINT

The screenshot shows an IDE interface with two main panes. The left pane displays the Java code for `Main.java`, which contains logic for handling multiple selection states (hoa, ladvice, intro, gadvice) and applying them to a text field `t`. The right pane shows the Abstract Syntax Tree (AST) for this code, with nodes colored according to their type: null (OC), green (IERS), yellow (RUCTOR), orange (PARAMETERS), blue (N_TYPE2), red (IETERS), purple (DIMENSIONS), magenta (WN_EXCEPTIONS), pink (block), grey (STATEMENTS), and various colored nodes for IfStatement, Expression, MethodInvocation, ThenStatement, ElseStatement, and other statements.

```
Notepad.java Actions.java Main.java X
output.setText(t.toString());
program.setText(t.eval(""));
equation.setText(base);
updateQuarkPanel();
)
});
apply.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        if (hoa.isSelected()) {
            t = t.apply(new hoa("h" + layerno));
        }
        if (ladvice.isSelected()) {
            t = t.apply(new ladvice("a" + layerno));
        }
        if (intro.isSelected()) {
            t = t.apply(new intro("i" + layerno));
        }
        if (gadvice.isSelected()) {
            t = t.apply(new gadvice("g" + layerno));
        }
        if (hoa.isSelected() || gadvice.isSelected()
            || ladvice.isSelected() || intro.isSelected())
            hoa.setSelected(false);
        gadvice.setSelected(false);
        ladvice.setSelected(false);
        intro.setSelected(false);
        equation.setText("F" + layerno + "(" + equation.g
            + ")");
    }
});
```

Outline ASTView X

- OC: null
- IERS (1)
- RUCTOR: 'false'
- PARAMETERS (0)
- N_TYPE2
- IETERS (1)
- DIMENSIONS: '0'
- WN_EXCEPTIONS (0)
- block [4443, 805]
- STATEMENTS (5)
 - IfStatement [4450, 73]
 - EXPRESSION
 - + MethodInvocation [4454, 16]
 - THEN_STATEMENT
 - ELSE_STATEMENT: null
 - IfStatement [4529, 80]
 - IfStatement [4615, 77]
 - IfStatement [4698, 81]
 - IfStatement [4785, 457]

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

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

JHIPSTER STARER IF YOU DON'T KNOW

Welcome to the JHipster Generator v2.17.0

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

Variability Model



mapping

```
1 package io.jhipster.generator.config;
2
3 import com.codahale.metrics.MetricRegistry;
4 import com.fasterxml.jackson.databind.ObjectMapper;
5 import com.zaxxer.hikari.HikariConfig;
6 import com.zaxxer.hikari.HikariDataSource;
7 import org.hibernate.cache.CacheManager;
8 import org.hibernate.cache.hazelcast.HazelcastCacheManager;
9 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory;
10 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.Autowired;
11 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
12 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
13 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
14 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
15 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
16 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
17 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
18 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
19 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
20 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
21 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
22 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
23 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
24 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
25 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
26 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
27 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
28 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
29 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
30 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
31 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
32 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
33 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
34 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
35 import org.hibernate.cache.hazelcast.HazelcastCacheManagerFactory.AutoWired;
```

Base Artefacts

Software Generator (derivation engine)

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

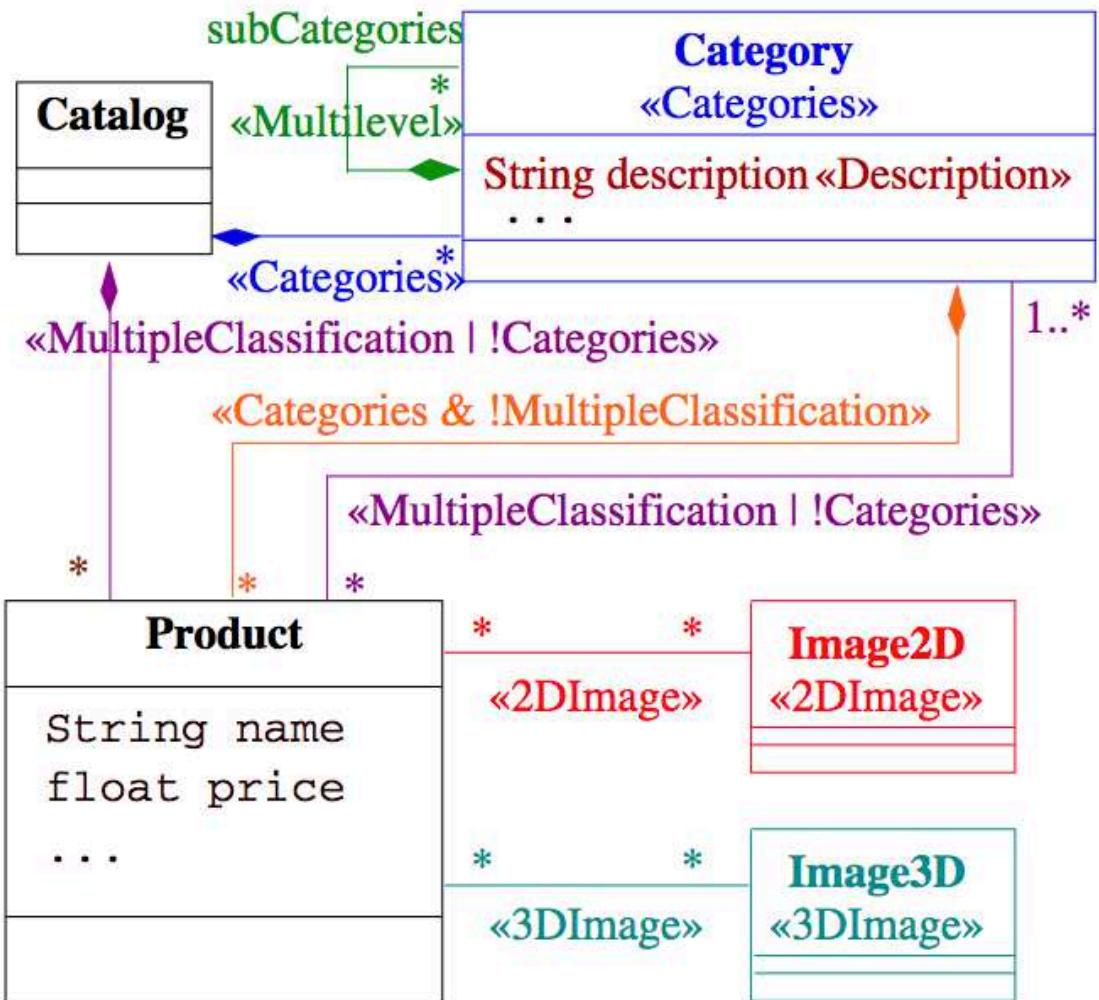
184 lines (165 sloc) | 9.69 KB

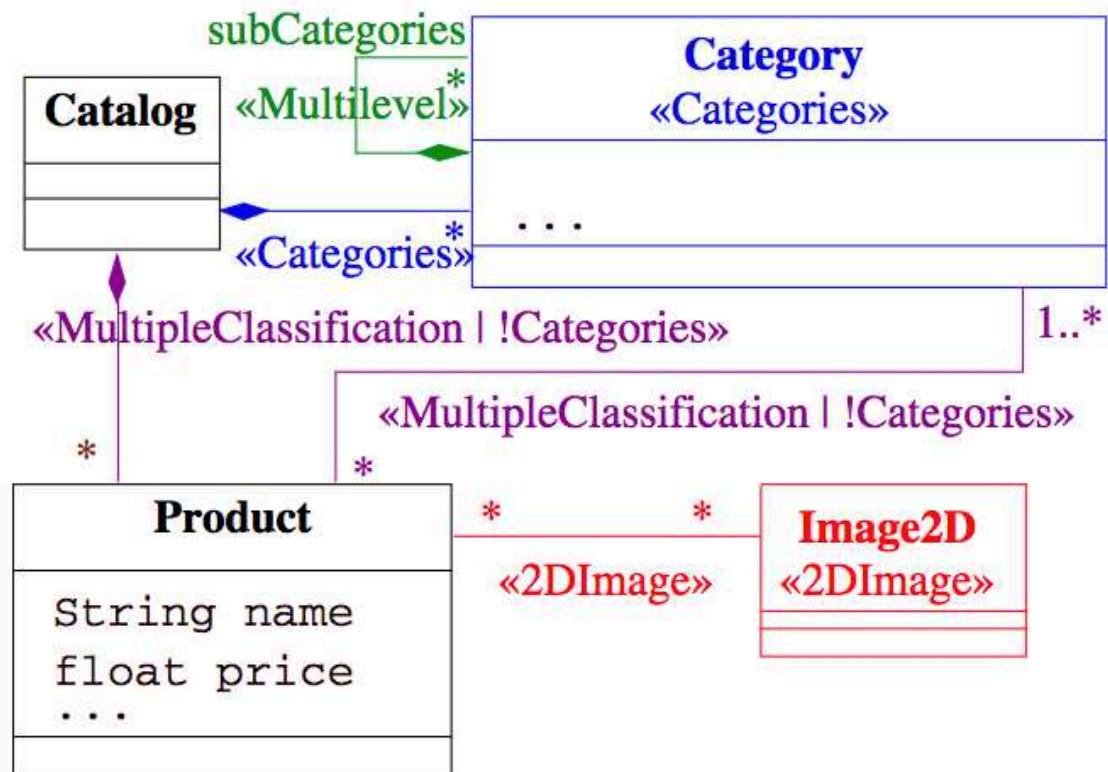
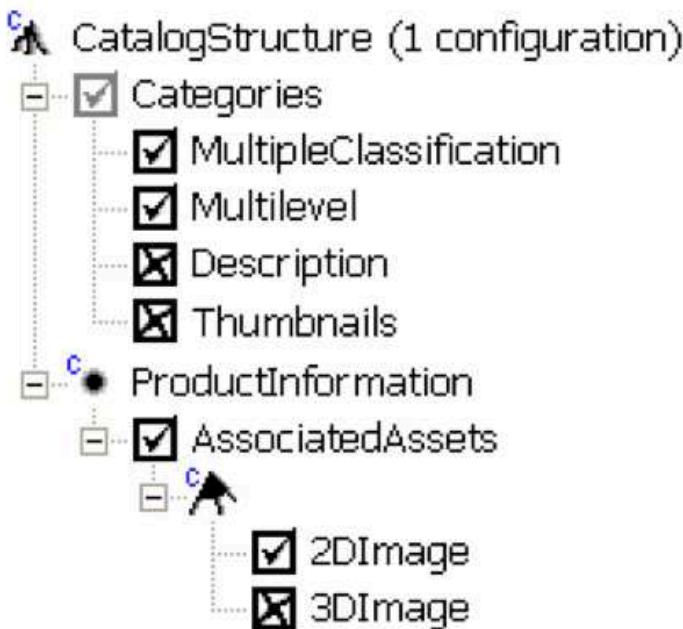
[Raw](#) [Blame](#) [History](#)   

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

▲ CatalogStructure (52 configurations)

- ● Categories
 - MultipleClassification
 - Multilevel
 - Description
 - Thumbnails
- ● ProductInformation
 - AssociatedAssets
 - 2DImage
 - 3DImage





Variability in the Video Domain (first example)

Bref

bref.

CANAL à 30 ans.

ETAPE 1 : DONNE TON PRENOM

MATHIEU

→ OK

Online Generator

← → C bref30ans.canalplus.fr/#c

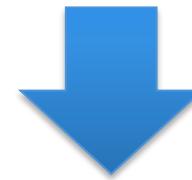
ETAPE 2 : CHOISIS 3 BONS SOUVENIRS



Variant



```
1 /*! Wildmoka - v0.0.0 - 2014-11-04
2 * http://wildmoka.com/
3 * Copyright (c) 2014 ; Licensed *
4 var requirejs=require,define;!func
5 return("input"+c||"button"==c)&
6 if(h[0]==a,a.delegateTarget=this,!j)
7 g=fb.trim(d),c.className=g&&(c.c
8 if(k.length){var r=k.data("and-")
9 },_mouseStart:function(){return!0
10 },show:function(){this._flashObj.s
11 d.append(e);var f=1,g=[];a.each(b,
```



 bref-service.cloudapp.net/pintvservices/getEp?a1=RANDOM&a2=RANDOM&a3=RANDOM&



bref-service.cloudapp.net/pintvservices/getEp?a1=RANDOM&a2=RANDOM&a3=RANDOM&

```
"sq": ["dwlcjv", "1y60t3z", "1lyfhk", "wqzv0y",
"1xxivi2", "1oxnvtu", "lolbe9", "wvo06o", "1u6y5t2",
"1eqb8bw", "1j9aij7", "nr7jom", "1jmvt1y",
"1qgn9dh", "1bv7rka", "19ykyyw", "5znrg7",
"116hv1k"]
```



bref30cdn.wildmoka.com/vidv2/116hv1k_med.txt

```
#EXTINF:06.40,
http://bref30cdn.wildmoka.com/vidv2/116hv1k_med0.ts
#EXTINF:03.96,
http://bref30cdn.wildmoka.com/vidv2/116hv1k_med1.ts
#EXTINF:04.52,
http://bref30cdn.wildmoka.com/vidv2/116hv1k_med2.ts
#EXTINF:03.08,
http://bref30cdn.wildmoka.com/vidv2/116hv1k_med3.ts
```

```
}

1659055
[ DESCHIENS, DECAUNESGARCIA, BURGER]
: "DESCHIENS"
: "DECAUNESGARCIA"
: "BURGER"
:e24=wxjqk2&e18=xi82vf&e05=x2nief&e21=cr3hzu&e25=1bv7rka&e06=loxnvtu&e04=ppdjpp&e12=1pt9ic1&e28=
"OK"
[ml7ila, ly60t3z, 12eo6f2, ppdjpp, x2nief, loxnvtu, a7kxth, 1pt9ic1, nej6g3, 1hhuj2v, 1j9aij7,
: "ml7ila"
: "ly60t3z"
: "12eo6f2"
: "ppdjpp"
: "x2nief"
: "loxnvtu"
: "a7kxth"
: "1pt9ic1"
: "nej6g3"
: "1hhuj2v"
0: "1j9aij7"
1: "xi82vf"
2: "cr3hzu"
3: "wxjqk2"
4: "1bv7rka"
5: "5jjnew"
6: "f353uf"
7: "116hv1k"
```

- wget + curl = 363281 episodes
- 18 sequences, 400 « .ts »
- 63 alternatives for the 1st sequence
- And so on...

9 34 15 25 51 30 2 6 6 12 21 28 6 86 4 1

.DS_Store

blank.ts

jg0meq_med0.ts

vp1

vp2

vp3

vp4

vp5

vp6

vp7

vp8

vp9

vp10

vp11

vp12

vp13

vp14

vp15

vp16

vp17

vp18

lu6y5t2_med0.ts

lu6y5t2_med1.ts

lu6y5t2_med2.ts

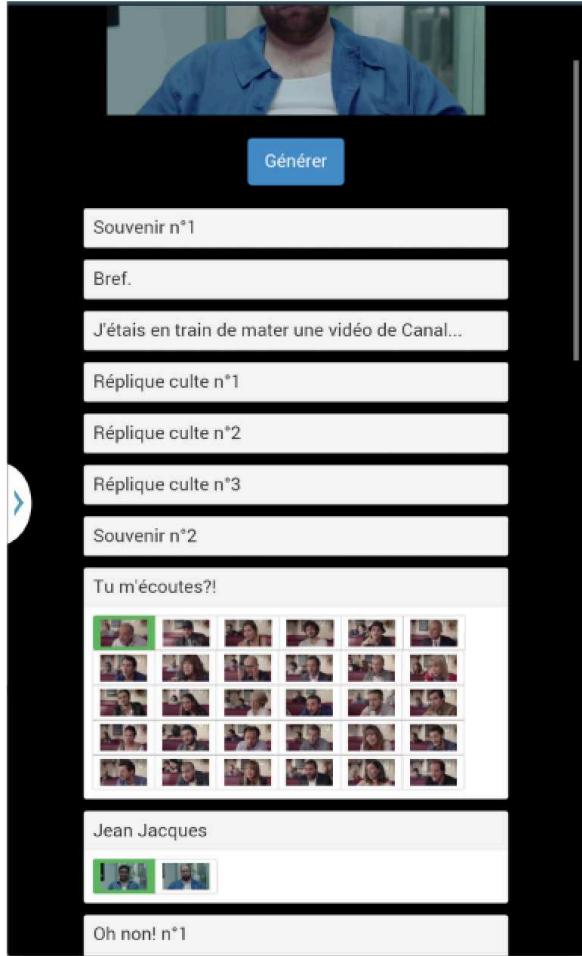
lu6y5t2_med3.ts

p8ocev_med0.ts

p8ocev_med1.ts

p8ocev_med2.ts





```
"sq": ["dwlcjv", "1y60t3z", "1lyfhk", "wqzv0y",
"1xxivi2", "1oxnvtu", "lolbe9", "wvo06o",
"1u6y5t2", "1eqb8bw", "1j9aij7", "nr7jom",
"1jmvl1y", "1qgn9dh", "1bv7rka", "19ykyyw",
"5znrg7", "116hv1k"]
```

← → C bref30cdn.wildmoka.com/vidv2/116hv1k_med.txt

```
#EXTINF:06.40,
http://bref30cdn.wildmoka.com/vidv2/116hv1k_med0.ts
#EXTINF:03.96,
http://bref30cdn.wildmoka.com/vidv2/116hv1k_med1.ts
#EXTINF:04.52,
http://bref30cdn.wildmoka.com/vidv2/116hv1k_med2.ts
#EXTINF:03.08,
http://bref30cdn.wildmoka.com/vidv2/116hv1k_med3.ts
```

.DS_Store
blank.ts
jg0meq_med0.ts
vp1
vp2
vp3
vp4
vp5
vp6
vp7
vp8
vp9
vp10
vp11
vp12
vp13
vp14
vp15
vp16
vp17
vp18

1u6y5t2_med0.ts
1u6y5t2_med1.ts
1u6y5t2_med2.ts
1u6y5t2_med3.ts
p8ocev_med0.ts
p8ocev_med1.ts
p8ocev_med2.ts

Figure 2: Re-engineering of the novel configurator (excerpt): users can now select a specific video for the 18 variation points identified during the reverse engineering of the original generator

Variability in the Video Domain (second example)



Generator
~ composition of
video sequences



**video
variants**



Generator
~ composition of
video sequences

**video
variants**

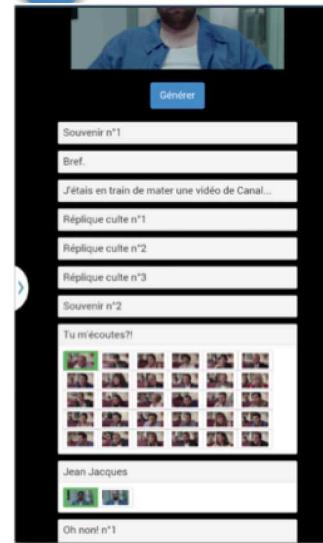
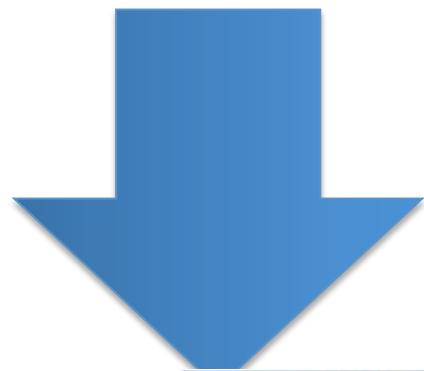




```
foo1.videogen ✘

mandatory videoseq v1 "https://www.youtube.com/watch?v=PjNi1uYhV5w"
optional videoseq v2 "v2/folder/v2.mp4"
alternatives v3 {
    videoseq v31 "v3/seq1.mp4"
    videoseq v32 "v3/seq1.mp4"
    videoseq v33 "v3/seq1.mp4"
}

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



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

foo1.videogen

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

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

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

configurable
generator
of video generator

Website/online

- Random generation
- Configurator
- Game
- ...



foo1.videogen ✘

```
mandatory videoseq v1 "https://www.youtube.com/watch?v=PjNi1uYhV5w"
optional videoseq v2 "v2folder/v2.mp4"
alternatives v3 {
    videoseq v31 "v3/seq1.mp4"
    videoseq v32 "v3/seq1.mp4"
    videoseq v33 "v3/seq1.mp4"
}
alternatives v4 {
    videoseq v41 "v4/seq1.mp4"
    videoseq v42 "v4/seq1.mp4"
}
mandatory videoseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"
```

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

#2 How to transform
models/programs?



#3 How to manage
variability/variants?

#4 How do frameworks
internally work?

Variability in the Video Domain (third example)



What are the differences?

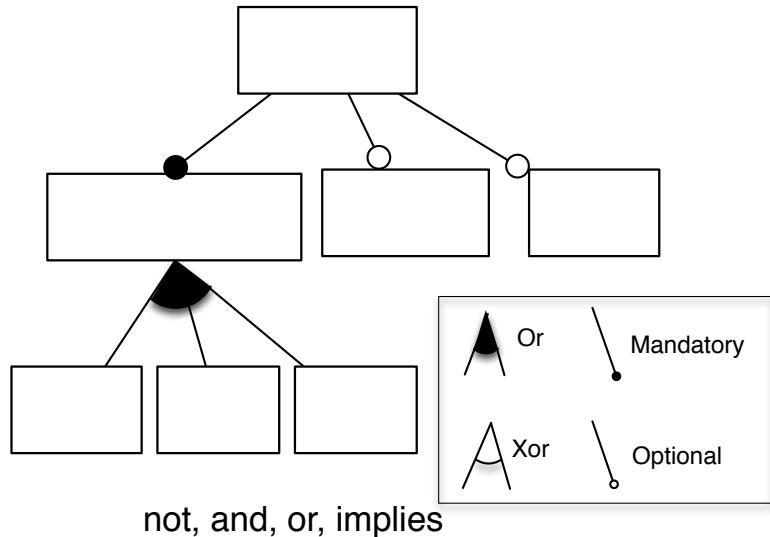




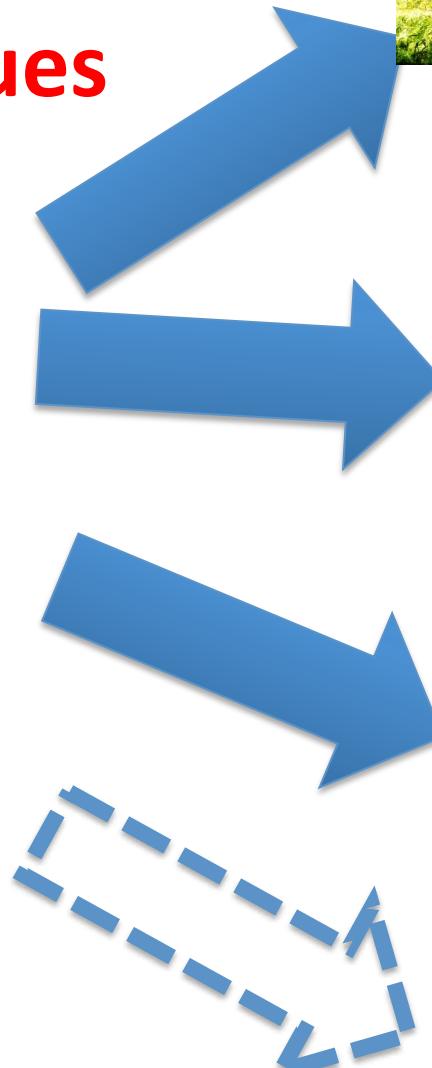
aka what is the variability of a video?



We synthesize video sequence variants with variability techniques



Variability Models (feature models)



Why?

**Industrial needs:
consumer and provider of
video algorithms have severe**

**difficulties to test their
algorithms on different kinds
of inputs.**



Test algorithms on different kinds of inputs that influence execution time, precision, and/or recall



Algorithm 1

0.63



0.81

Algorithm 2

0.93

Algorithm 3

0.82



0.43

0.92

0.81

0.8



0.39

0.03

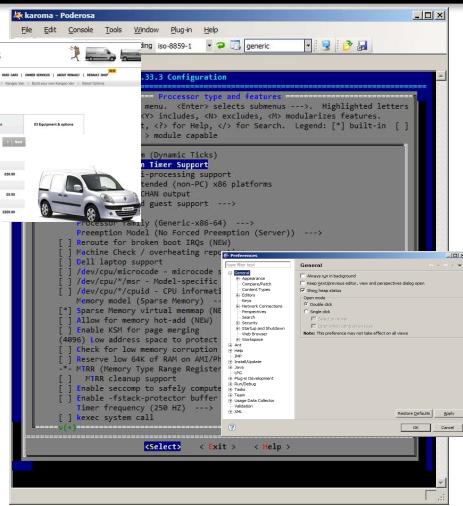
0.01

Why?

Problem: collecting videos is a key economic problem.

Solution: hundreds of video sequences with different characteristics.





Feature Model

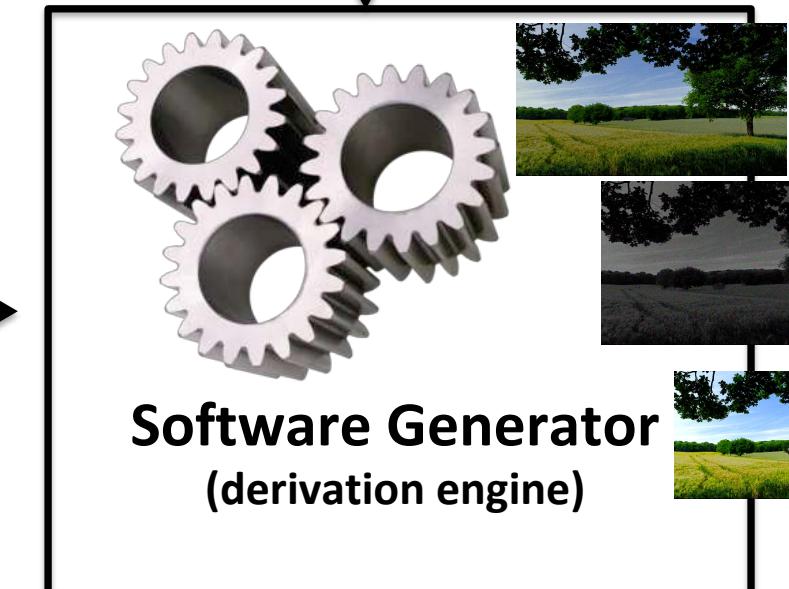
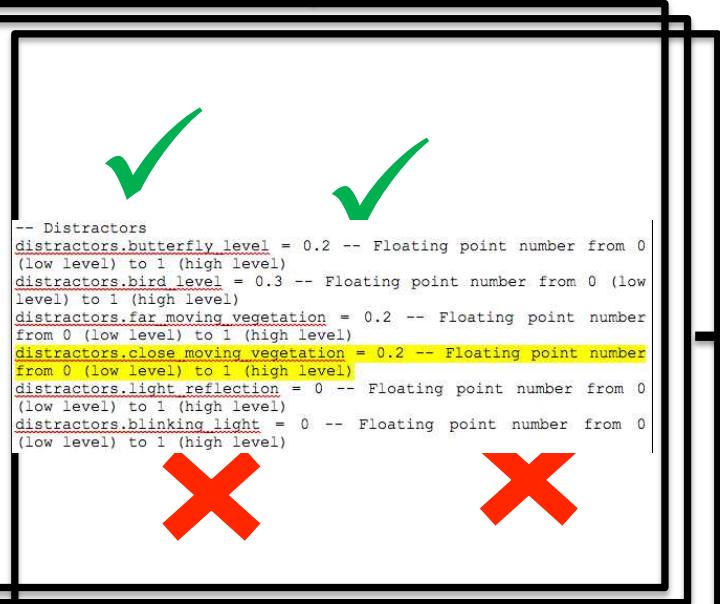
mapping

```

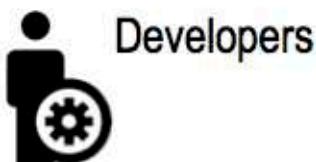
printC"-->Step9")
if (CFG.distractors.close_moving_vegetation~=0) then
    windvect5, precwindvect5, newwindvect5 =
    generate_wind_vector_field2(workwidth, workheight, 256, 1, 1, 35, picnum,
    precwindvect5, newwindvect5)
    windvectmul =
    windvect5:mul(24*CFG.distractors.close_moving_vegetation)
    globalvect = compose_vect(masque_feuilles_sombres, windvectmul, globalvect)
    hfvx, hfvy =
    windvect:mul(6*CFG.distractors.close_moving_vegetation):to_matrix()
    hfvx = MATRIX.multerm(hfvx, invdepthmat)
    hfvy = MATRIX.multerm(hfvy, invdepthmat)
    lfvect = windvect2:resize_bilinear(windvect2.Width, windvect2.Height/16)
    lfvect = lfvect:resize_bilinear(windvect2.Width, windvect2.Height)
    lfvx, lfvy = lfvect:mul(
    12*CFG.distractors.close_moving_vegetation):to_matrix()
    lfvx = MATRIX.multerm(lfvx, depthmat)
    lfvy = MATRIX.multerm(lfvy, depthmat*0.1)
    windvectcomp = VECT2D.new_from_matrices(MATRIX.addterm(lfvx, hfvx),
    MATRIX.addterm(lfyv, hfvy))
    globalvect = compose_vect(masque_ble, windvectcomp, globalvect)
    globalvect = compose_vect(masque_orge, windvectcomp, globalvect)
    globalvect = compose_vect(masque_ble_fond, windvectcomp, globalvect)
end

printC"-->Step10")

```



Old Approach



Developers

*modify
 N times*

Video Sequences Generator

N Configuration Files



...



generates

N Video Sequences



VM Approach

Developers and Domain Experts



generates

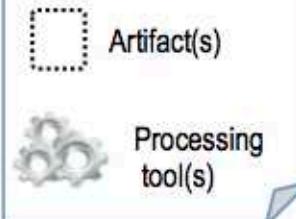


VM interpreter, and
configuration files
customizer

*model
1 time*

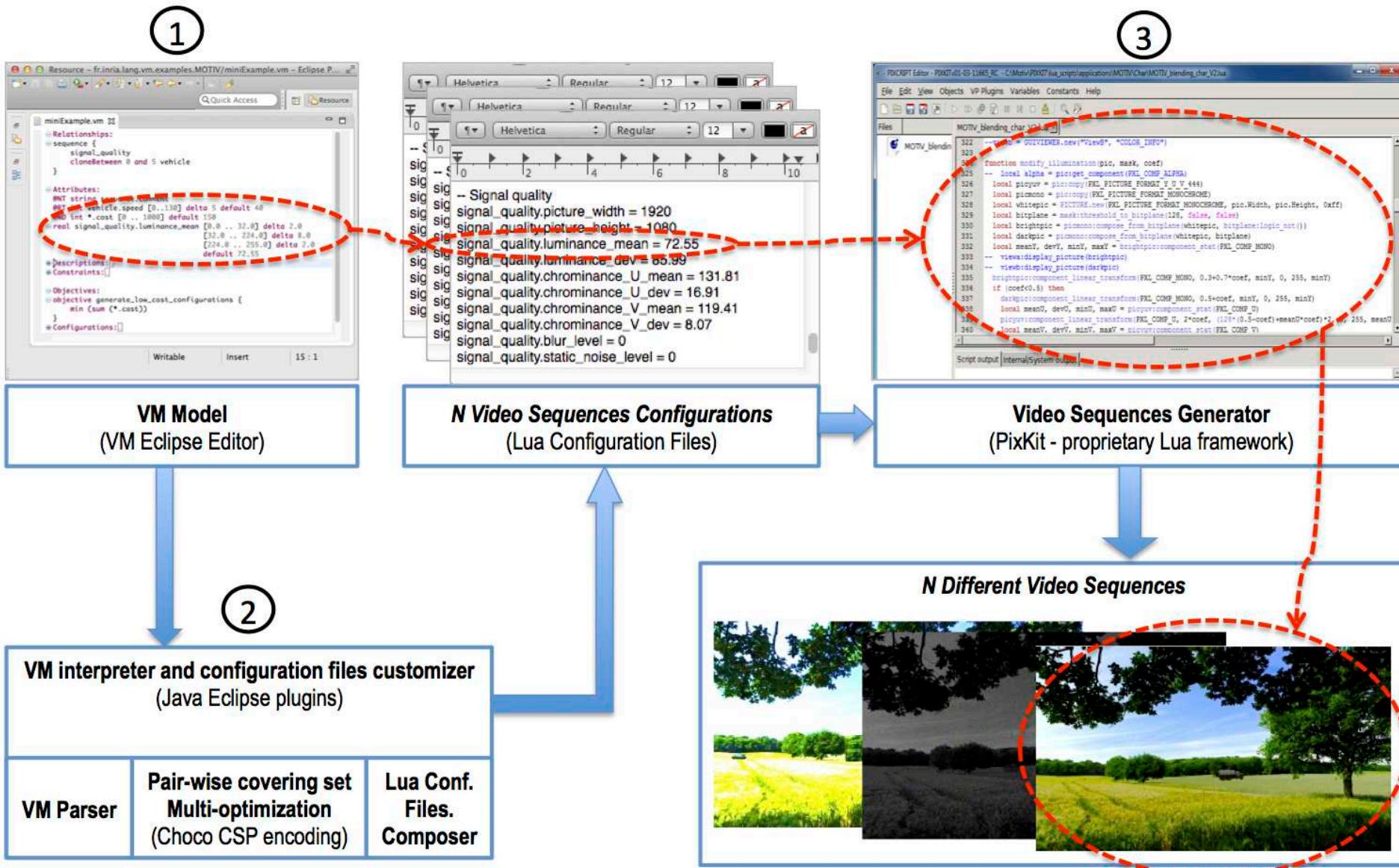


VM model



Artifact(s)

Processing
tool(s)



(configuration file)

```
-- Distractors
distractors.butterfly level = 0.2 -- Floating point number from 0
(low level) to 1 (high level)
distractors.bird level = 0.3 -- Floating point number from 0 (low
level) to 1 (high level)
distractors.far moving vegetation = 0.2 -- Floating point number
from 0 (low level) to 1 (high level)
distractors.close moving vegetation = 0.2 -- Floating point number
from 0 (low level) to 1 (high level)
distractors.light reflection = 0 -- Floating point number from 0
(low level) to 1 (high level)
distractors.blinking light = 0 -- Floating point number from 0
(low level) to 1 (high level)
```

```
print(">Step9")
if (CFG.distractors.close moving vegetation~=0) then
    windvect5, precwindvect5, newwindvect5 =
generate_wind_vector_field2(workwidth, workheight, 256, 1, 1, 35, picnum,
precwindvect5, newwindvect5)
    windvectmul =
windvect5:mul(24*CFG.distractors.close moving vegetation)
    globalvect = compose_vect(masque_feuilles_sombres, windvectmul, globalvect)
    hfvx, hfvy =
windvect0:mul(6*CFG.distractors.close moving vegetation):to_matrix()
    hfvx = MATRIX.multerm(hfvx, invdepthmat)
    hfvy = MATRIX.multerm(hfvy, invdepthmat)
    lfvect = windvect2:resize_bilinear(windvect2.Width, windvect2.Height/16)
    lfvect = lfvect:resize_bilinear(windvect2.Width, windvect2.Height)
    lfvx, lfvy = lfvect:mul(
12*CFG.distractors.close moving vegetation):to_matrix()
    lfvx = MATRIX.multerm(lfvx, depthmat)
    lfvy = MATRIX.multerm(lfyv, depthmat*0.1)
    windvectcomp = VECT2D.new_from_matrices(MATRIX.addterm(lfvx, hfvx),
MATRIX.addterm(lfyv, hfvy))
    globalvect = compose_vect(masque_ble, windvectcomp, globalvect)
    globalvect = compose_vect(masque_orge, windvectcomp, globalvect)
    globalvect = compose_vect(masque_ble_fond, windvectcomp, globalvect)
end
print(">Step10")
```

(Lua code)

Defects detection

Benchmarking

Incremental design

Performance prediction



Algorithm 1

0.63

0.81

0.43

0.39

Algorithm 2

0.93

0.92

0.3

0.03

Algorithm 3

0.82

0.81

0.8

0.01

Other references

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

Other references

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