



# Where Are My Constraints and What Do They Constrain?

SPLC Keynote | Thomas Thüm | September 8th, 2021

# Where Are My Features ?

Part I

# **My Claim: Features are Everywhere**

Need Evidence?

# Features Are Everywhere: Cars

8/10 search results for „configurator“ are car configurators

Customise your wheel



Finish

15" black machined-face alloy wheels (5-double-spoke)



Cap colour

Black small centre cap



Google configurator

About 20,800,000 results (0.54 seconds)

**Brabus**  
https://www.brabus.com / configurator  
**Configurator - BRABUS**  
Brabus black metallic · Polar white · Iridium silver metallic · Designo mystic blue bright · Emerald green metallic · Selenite grey metallic · Hyacinth red metallic

**Porsche**  
https://www.porsche.com / international / modelstart  
**Porsche Car Configurator - Porsche AG**  
Porsche Car Configurator. Porsche Code All Models. Choose your favorite model. Porsche - 718, 718, Porsche - 911, 911, Porsche - Taycan, Taycan.

People also ask

What is a configurator tool?

Can you build your own Ferrari?

Can you customize a Porsche?

How many Porsche cars are there in India?

**Wikipedia**  
https://en.wikipedia.org / wiki / Configurator  
**Configurator - Wikipedia**  
Configurators serve as an important tool for choice navigation. Configurators have been widely used in e-Commerce. Examples can be found in different industries ...  
Advantages · Enabler of mass customization · Existing configuration paradigms

**Bentley Motors**  
https://www.bentleymotors.com / misc / car-configurator  
**Car Configurator - Bentley Motors**  
select a vehicle model to choose from its derivatives. Flying Spur. Select. Continental. Select. Bentayga. Select. The Bentley Configurator. (Change).

**Mercedes-Benz**  
https://www.mercedes-benz.de / conf... · Translate this page  
**Konfigurator - Mercedes-Benz.de**  
Car Configurator | Vehicle Search | Lead and Contact Service | CIAM | Mercedes-Benz Marketplace DE | Digital Service Drive Payment

**AMG**  
https://www.mercedes-amg.com / vehicles / get-your-a...  
**Get your very own AMG in just three steps - Mercedes-AMG**  
An extra charge applies when you pick up your new AMG vehicle in Affalterbach. Further information is available from your dealer and the Mercedes-Benz customer ...

**BORBET**  
https://www.borbet.de / configurator  
**Configurator - BORBET**  
Geben Sie Ihre Schlüsselnummer ein oder geben Sie die Fahrzeugdaten manuell an. Nutzen Sie unsere Grafik, um die Daten in Ihrem Fahrzeugchein oder Ihrer ...

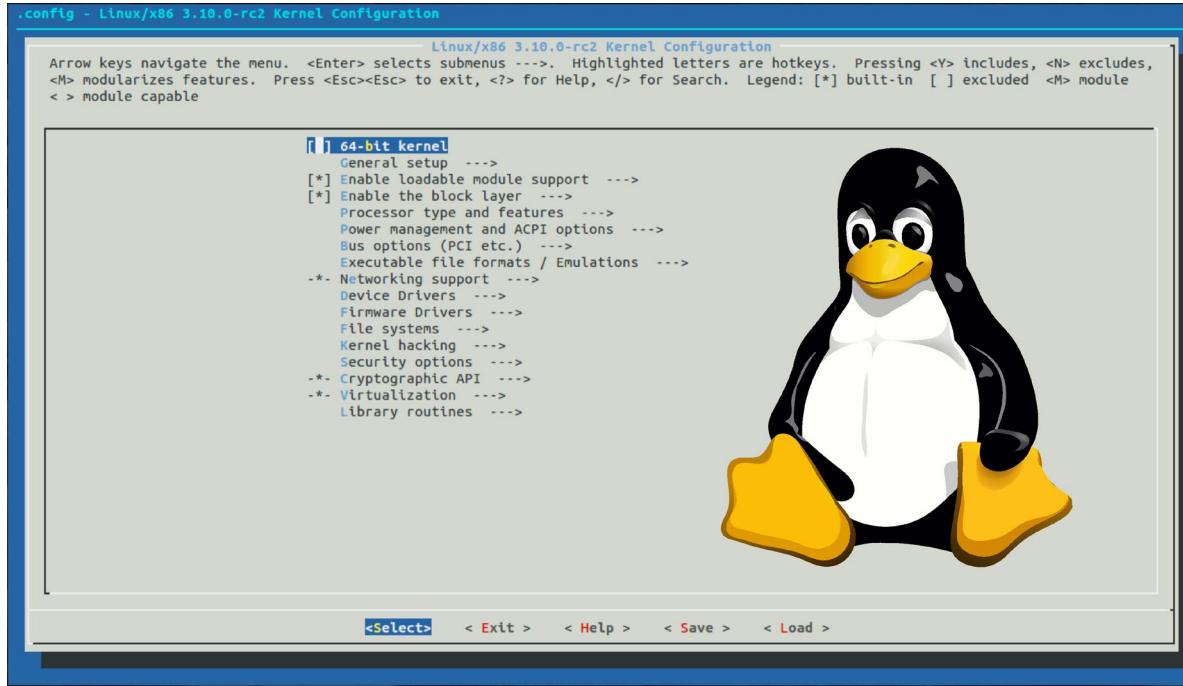
**Ferrari**  
https://carconfigurator.ferrari.com /  
**Configure your Ferrari: Ferrari Official Car Configurator**  
Customize your Ferrari with the Official Car Configurator. Choose colors, design, setup, wheels, and customize your Ferrari in every detail.

**Apple**  
https://support.apple.com / apple-configurator  
**Apple Configurator - Official Apple Support**  
Access resources, contact options and learn about mass configuration and iOS deployment options for your institution's devices with Apple Configurator.

**Skoda**  
https://cc.skoda-auto.com /  
**SKODA AUTO Car Configurator**  
Car Configurator. Choose the country and find links to important Car Configurator pages. Western Europe, Belgium / BEL, Belgium / FRBelgium / NL.

# Features Are Everywhere: Operating Systems

„If Linux would not exist, your research would not be needed.“



# Features Are Everywhere: IDEs

**46,863,414** solutions installed directly from Eclipse!



 Java
C/C++ Development Tools
Data Tools Platform
Git integration for Eclipse ✓
Java Development Tools ✓
Java EE Developer Tools
JavaScript Development Tools
Maven Integration for Eclipse ✓
Mylyn Task List
PHP Development Tools (PDT)

# Features Are Everywhere: Financial Products

Fritsch et al. SPLC'20

# The Benefits of a Feature Model in Banking

## Experience Report

Claudia Fritsch  
KfW  
Frankfurt am Main, Germany  
[claudia.fritsch@kfw.de](mailto:claudia.fritsch@kfw.de)

Richard Abt  
KfW  
Frankfurt am Main, Germany  
[richard.abt@kfw.de](mailto:richard.abt@kfw.de)

Burkhardt Renz  
Technische Hochschule Mittelhessen  
Gießen, Germany  
[burkhardt.renz@mni.thm.de](mailto:burkhardt.renz@mni.thm.de)

## ABSTRACT

This experience report describes the surprisingly beneficial introduction of feature modeling at KFW, a government promotional bank. On behalf of the government and based on promotional directives, KFW grants retail loans to small and medium enterprises, business founders, self-employed professionals, municipalities and private individuals. The promotional directives, called programs, define mandatory and optional properties of these loans. We have now successfully built a feature model from these properties.

Our feature model will be presented with its outstanding characteristic, which is an additional subtree containing the programs as features. Complete and correct cross-tree constraints will also allow us to analyze and scope the portfolio, reduce complexity, and speed-up time-to-market. This is the advent of product line development at KfW.

In order to standardize our portfolio, we have subsequently developed tools on top of the feature model, namely, a browser-based,

ACM Reference Format

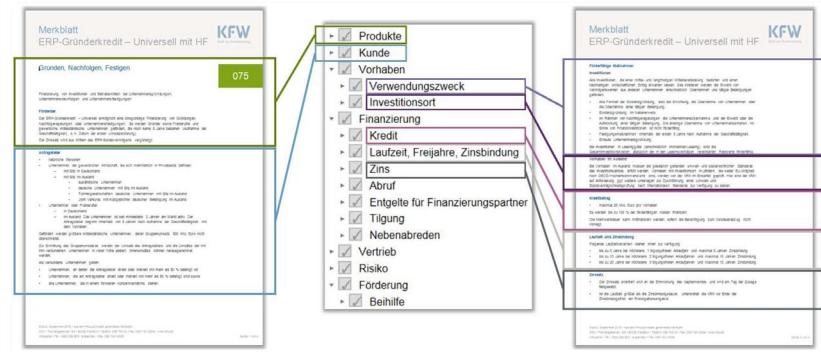
Claudia Fritsch, Richard Abt, and Burkhardt Renz. 2020. The Benefits of a Feature Model in Banking: Experience Report. In *24th ACM International Systems and Software Product Line Conference (SPLC '20), October 19–23, 2020, MONTREAL, QC, Canada*. ACM, New York, NY, USA, 11 pages. <https://doi.org/10.1145/3382025.3414946>

## 1 INTRODUCTION

## 1.1 KfW

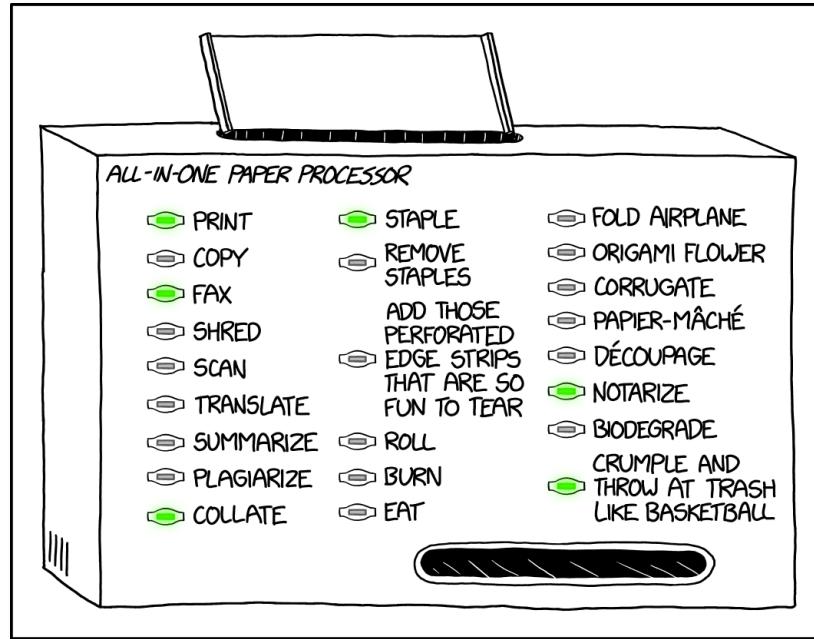
Founded in 1948 as a bank under public law and equipped with funds of the European Recovery Program (ERP, "Marshall Plan"), the Kreditanstalt für Wiederaufbau (KfW) has been giving loans to companies, private individuals and German municipalities for more than 70 years.

Today, KfW is one of the world's leading promotional banks, and one of Germany's largest banks. On behalf of the Federal Republic of Germany and the Federal States, KfW finances projects worldwide,



# Features Are Everywhere: Printers

More features every year and lower quality?



# Features Are Everywhere

Emails on product-line topics sent to me from many places on earth

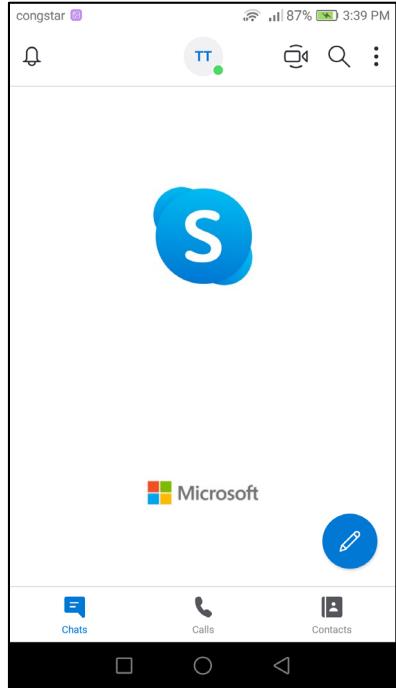


# Where Are My Feature Interactions ?

Part I

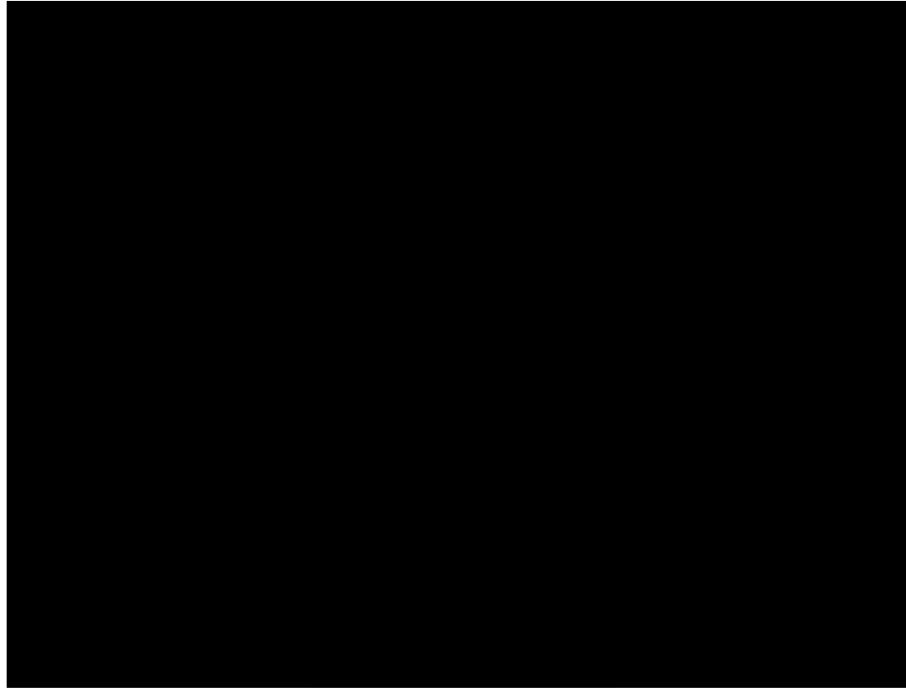
# Me Experiencing a Feature Interaction in 2012

Which of 3.5 million Android apps interact? Where to document? Who to blame?

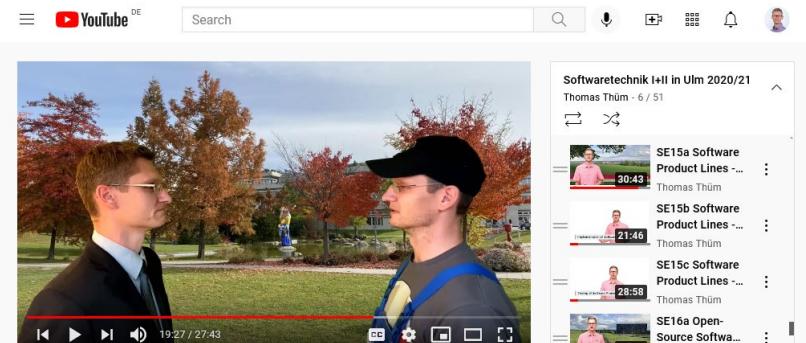


# Me Experiencing a Feature Interaction in 2019

Interaction involves software and hardware. Where to document? Who to blame?



# Me Ordering Bug Bounties for My SE Lecture



A screenshot of a YouTube video player. The video shows a man in a suit and another man in a cap and t-shirt from the side, standing outdoors. The video player interface includes a search bar, a play button, and a progress bar showing 19:27 / 27:43. Below the video, the channel name is ULM UNIVERSITY, and the video title is SE02b Requirements - Software Engineering (Softwaretechnik) 2020/21. It has 283 views and was posted on Nov 12, 2020. The video description at the bottom reads: "Was zeichnet gute Anforderungen aus und wie können wir die ermitteln? Link zu den Foliern: <https://www.uni-ulm.de/fileadmin/webs...>".

Softwaretechnik I+II in Ulm 2020/21  
Thomas Thüm - 6 / 51

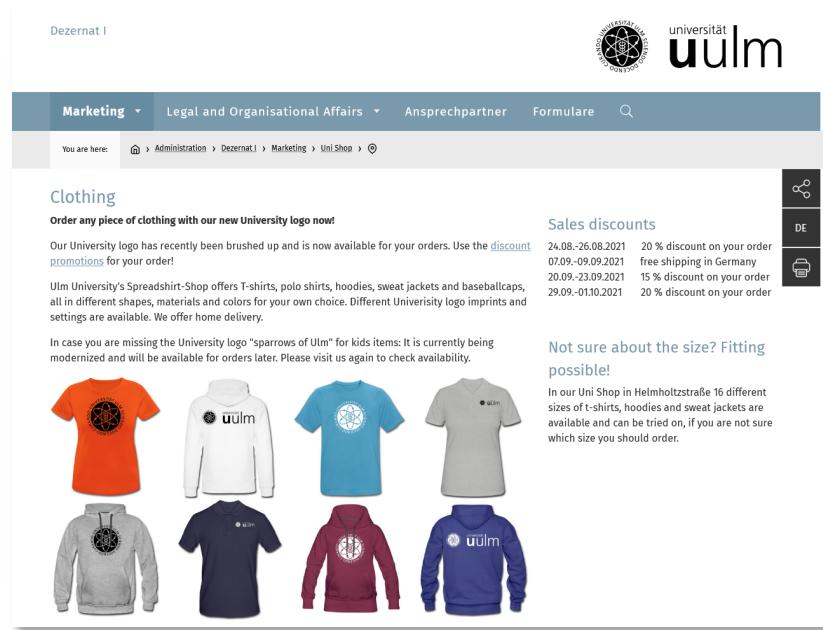
- SE15a Software Product Lines ... 30:43 Thomas Thüm
- SE15b Software Product Lines ... 21:46 Thomas Thüm
- SE15c Software Product Lines ... 28:58 Thomas Thüm
- SE16a Open-Source Softwa... 30:52 Thomas Thüm

All Presentations Listenable

Wissenschaftlich Schreiben und...  
Thomas Thüm 150 views · 3 months ago

Henning Beck: Universität Ul...  
Haus der Wissen

ANALYTICS EDIT VIDEO



The University of Ulm's Uni Shop page for clothing. The header features the university logo and navigation links for Marketing, Legal and Organisational Affairs, Ansprechpartner, Formulare, and a search bar. The breadcrumb navigation shows You are here: Administration > Dezernat I > Marketing > Uni Shop.

## Clothing

Order any piece of clothing with our new University logo now!

Our University logo has recently been brushed up and is now available for your orders. Use the [discount promotions](#) for your order!

Ulm University's Spreadshirt-Shop offers T-shirts, polo shirts, hoodies, sweat jackets and baseballcaps, all in different shapes, materials and colors for your own choice. Different University logo imprints and settings are available. We offer home delivery.

In case you are missing the University logo "sparrows of Ulm" for kids items: It is currently being modernized and will be available for orders later. Please visit us again to check availability.

## Sales discounts

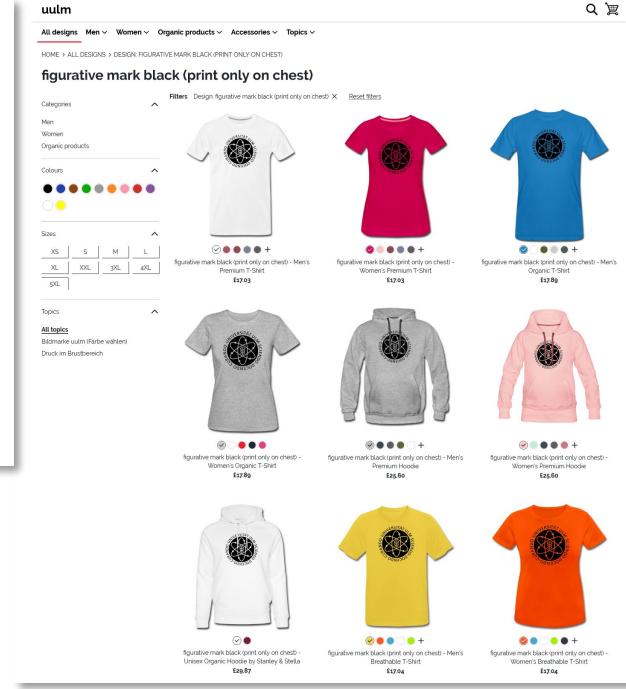
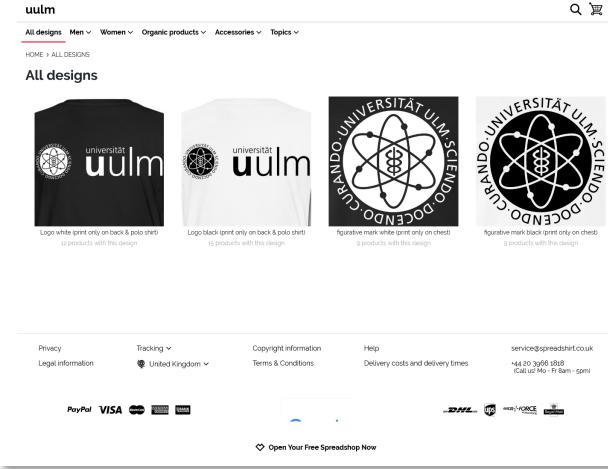
Date	Offer
24.08.-26.08.2021	20 % discount on your order
07.09.-09.09.2021	free shipping in Germany
20.09.-23.09.2021	15 % discount on your order
29.09.-01.10.2021	20 % discount on your order

Not sure about the size? Fitting possible!

In our Uni Shop in Helmholtzstraße 16 different sizes of t-shirts, hoodies and sweat jackets are available and can be tried on, if you are not sure which size you should order.



# Me Ordering Bug Bounties for My SE Lecture



# Me Ordering Bug Bounties for My SE Lecture



## Wir brauchen eine Entscheidung von Dir

Hallo,

vielen Dank für Deine Bestellung! Bevor wir Deine Ware bedrucken können, brauchen wir eine Entscheidung von Dir.

### Bei der Produktion sind wir auf ein kleines Problem gestoßen:

Die Farbe Deines Designs ist der Farbe Deines Produkts zu ähnlich. Wenn der Kontrast zwischen Druck- und Stofffarbe zu gering ausfällt, wird das Design erfahrungsgemäß schlecht zu erkennen sein.

### Unser Lösungsvorschlag:

Wir können die Farbe des Produkts für Dich ändern. In einzelnen Fällen ist es auch möglich, die Farbe des Designs anzupassen. Oder wir belassen die Bestellung genauso wie sie ist, weil Du Dich bewusst für einen geringen Kontrast entschieden hast.

[Bestellung einsehen](#)

Bitte kontaktiere schnellstmöglich unseren Kundenservice, indem Du auf diese Mail antwortest oder anrufst unter 0341 59 400 5900 (Mo-Fr 9-18 Uhr)

Wenn wir bis zum 02.08.2021 keine Antwort erhalten, werden wir Deine Bestellung stornieren und gegebenenfalls den Rechnungsbetrag erstatten.

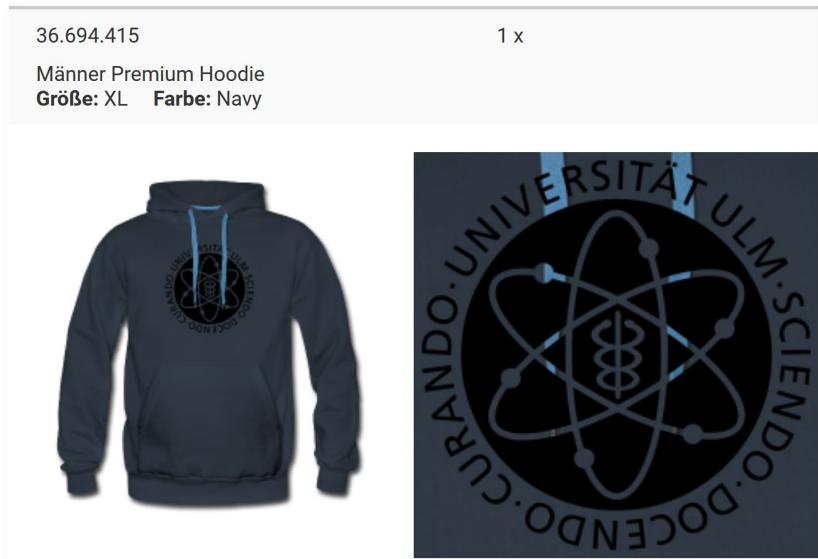
Wir freuen uns auf Deine Rückmeldung.

Viele Grüße  
Dein Team von Spreadshirt



# Me Ordering Bug Bounties for My SE Lecture

Feature interaction without software. Easy to document. Can be checked automatically.



**Männer Premium Hoodie**  
Größe: M  
Farbe: Grau meliert  
Anzahl: 1  
Artikel-Nr.: **36694416**

Every unwanted feature interaction waits to be fixed or at least documented in form of a constraint.

# Where Are My Constraints?

Part I

1 Option Compatibility Matrix (August, 2021): ThinkPad X-Series

C3	A	B	W	X	Y	Z	AA	AB	AC	AD	AH
1	Option Compatibility Matrix (August, 2021): ThinkPad X-Series		X390(#20Q0,20Q1,20SC,20S)	X1 Extreme(#20MF,20MG)	X1 Yoga 3rd Gen(#20LD,20L)	X280(#20KE,20KF)	X1 Carbon 6th Gen(#20KG,20K)	X1 Yoga 2nd Gen(#20JF,20J)	X1 Carbon 5th Gen(#20HQ,20H)	X270(#20HM,20HN,20K5,20K)	
2	Description	Part									
976	Lenovo Active Pen 2	GX80Q75526		314	314						
977	Lenovo Active Pen 2	GX80Q75527		314							
978	Lenovo Active Pen 2	GX80Q75528		314							
979	Lenovo Active Pen 2 with Battery	4X80Q75521		314							
980	Lenovo Active Pen 2 without Battery	4X80Q75522		314							
981	Lenovo Active Pen 2 with Battery	4X80Q75523		314							
982	Lenovo Active Pen 2 with Battery	4X80Q75524		314							
983	Lenovo ThinkPad Pen Pro X1 Yoga	4X80K32539									
984	Lenovo Pen Pro-ROW	4X80R02889		109							
985	Lenovo Pen Pro-AP	4X80Q97739		109							
986	Lenovo Pen Pro-MEA	4X80Q97740		109							
987	Lenovo Pen Pro-LA	4X80Q97741		109							
988	Lenovo Pen Pro-Israel	4X80T37573		109							
989	ThinkPad Pen Pro - 6	4X80U90632									
990	ThinkPad Pen Pro - 7	4X80U90631									
992	Lenovo Mod Pen	4X81B07782									
993	Lenovo Digital Pen	4X81C66286									
994	Lenovo Precision Pen	4X80Z50965									
995	ThinkPad Pen Pro-10	4X81C96610									
996	#End										
997											
998											
999											

A		B
236	313	<p>Compatible with 45W or 65W slim-tip charged notebooks only</p> <p>Only can support touch screen system.</p> <p>4X80N95874/GX80N07827:KR,Colombia; 4X80Q75521/GX80Q75525:Jordan,PH, Saudi Arabia, Singapore, Thailand</p> <p>4X80Q75522/GX80Q75526:Argentina,Bolivia,Brazil,Colombia,Ecuador,Malaysia, Mexico, Paraguay, Peru, Uruguay, Venezuela;</p> <p>4X80Q75523/GX80Q75527:Israel, Russia, UAE</p> <p>4X80Q75524/GX80Q75528:Algeria, Azerbaijan, Bahrain, Belarus, Botswana, Chile, Cote d ivoire, Egypt, India, Indonesia, KZ, Kenya, Kuwait, Lebanon, Moldova, Morocco, Nigeria, Oman, Pakistan, Qatar, SA, Sri Lanka, Tunisia, Uganda, Ukraine, UAE</p> <p>4X80N95873/GX80N07825:Albania,Angola,AU,Austria,Bangladesh,Belgium, BA, Bulgaria, Canada, Croatia, Cyprus, CZ, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, HK, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, LU, Macedonia, NL, New Zealand, Norway, Poland, Portugal, Romania, Serbia and Montenegro, Slovakia, Slovenia, Spain, Sweden, CH, Taiwan, Turkey, TM, UK, US, Uzbekistan, Vietnam</p>
237	314	4X80N95873:CN,JP; GX80N07824:CN; GX80N20629:JP
238	315	If assemble two more 3.5" Hard Drive , the 3.5"HDD bracket kit 4XF0Q63396 is needed.
239	316	Please ensure to use v44 BIOS or above.
240	317	Please ensure to use v30 BIOS or above
241	318	It can only be used on 900W power supply model, but not on 690w power supply model.
242	319	The 2.5" bracket (4XF0G94539 or 4XF0P01009) may be needed when install a 2.5" HDD or SSD based on user's configuration
243	320	The 2.5" bracket (4XF0P01010) may be needed when install a 2.5" HDD or SSD based on user's configuration
244	321	Only compatible with those that bundled a 45W USB-C adapter
		With AC power adapter connected: PXE boot supported. Wake On LAN from Hibernation, or Power-Off mode. MAC address pass through
245	322	Without AC power adapter connected: PXE boot supported. MAC address pass through
		For the computer handle with a hole, install a locking clip. For the computer without a hole, install the two cage nuts on the mounting flange. Align the holes in the stopper with the

# Lenovo's Option Compatibility Matrices

- 7 Excel files (current models) + archive for old models
- First file with 32 tables (series)
- Table for ThinkPad X has 28 columns (models) and >500 rows (accessories)
- 14k cells contain >400 different “footnotes” (explanations for incompatibilities)

Feature interactions are documented.  
It is up-to the customer to check  
these tables before bying accessories.

## Knowledge Base & Guides

### Accessories and Options Compatibility Matrix (OCM)

The Lenovo OCM are Microsoft Excel files that have compatibility information for Lenovo accessories.  
To quickly share this page, use this url: [www.lenovo.com/accessoriesguide](http://www.lenovo.com/accessoriesguide)

Description	Version
ThinkPad, ThinkCentre, ThinkStation, Ideapad and Ideacentre Option Compatibility Matrix	Aug 2021
Commercial Monitors - Option Compatibility Matrix	Aug 2021
Consumer Monitors - Option Compatibility Matrix	Aug 2021
Storage - Option Compatibility Matrix	November 2019
ThinkServer - Option Compatibility Matrix	October 2019
ThinkSystem and System X - Option Compatibility Matrix	October 2019
Network function support - Option Compatibility Matrix	Aug 2021

### Archive OCM (For older product)

Description
Archive - ThinkPad, ThinkCentre, ThinkStation, Ideapad and Ideacentre Option Compatibility Matrix

# Constraints in Web Configurators: ThinkPad

Thüm et al. CONFWS'18

Display

14.0" FHD (1920x1080), LED backlight, 300 nits, 16:9 aspect ratio, 700:1 contrast ratio, 72% gamut, 170° viewing angle, IPS, Touch 0

14.0" WQHD (2560x1440), LED backlight, 300 nits, 16:9 aspect ratio, 700:1 contrast ratio, 72% gamut, 170° viewing angle, IPS, Touch + £91.20

14.0" HDR WQHD (2560x1440) with Dolby Vision™, LED backlight, 500 nits, 16:9 aspect ratio, 1500:1 contrast ratio, 100% gamut, 170° viewing angle, IPS, Touch  
Please note this display is only available with WWAN/mobile broadband.

LOADING...  
SELECTED

# Constraints in Web Configurators: Toyota

Thüm et al. CONFWS'18

**Your AYGO**

5 Door Hatchback x-play 1.0 Petrol (69 hp)  
Automatic (Front Wheel Drive - FWD)

Retail price	<b>£11,610.00</b>
Red Pop	
Gleam fabric	
15" black machined-face alloy wheels (5-double-spoke)	£500.00
Black small centre cap	
<b>Total</b>	<b>£12,610.00</b>

[Summary and save >](#)

**Your customisation** [Change customisation](#)

**Colours & wheels**

Red Pop	£500.00
15" colour-customisable alloy wheels (5 double-spoke)	£500.00
15" black machined-face alloy wheels (5-double-spoke)	£500.00
Black small centre cap	

**Interior trim**

Gleam fabric
--------------

**Total**

£12,610.00
------------

# Constraints Make Feature Interactions Explicit

## How to express constraints?

- Enumerate all valid configurations
  - Natural language
  - Compatibility matrices
  - List of rules
    - A and B implies C or D
  - Propositional logic
  - Decision models
  - Feature models
  - ...

## When to enforce constraints?

- No systematic enforcement or at runtime #lenovo
  - At load or compile time #spreadshirt #toyota
  - At design time #lenovo
  - Enforcement automated?

# What Is Your Favorite Example of a Feature Interaction?

Breakout Rooms

# What Do They Constrain?

Part II

# Do All Configurations Behave As Expected?

ACM TECHNEWS

## Xerox Scanners Found to Sometimes Alter Numbers

By IDG News Service

August 8, 2013

Comments

VIEW AS: SHARE:



A Ph.D student has discovered that Xerox scanners can randomly alter numbers on documents when reproducing them, if a specific combination of image quality and compression settings are used. Xerox admits the issue exists, and suggests using a higher-quality scan to avoid the problem.

Credit: IDG News Service

University of Bonn Ph.D. student David Kriesel has found that Xerox scanners sometimes randomly alter numbers on documents when reproducing them if a specific combination of image quality and compression settings are used.

Xerox acknowledges the problem and is advising customers to use a higher-quality scanner setting to avoid the problem.

When an image is scanned in TIFF mode, a pixel-for-pixel reproduction, the copy was identical to the original. However, when Kriesel used the image-compression feature, the numbers started getting mixed up. There appears to be a correlation between the font size and the scan's resolution.

Kriesel was able to narrow the problem down to the way the scanner's JBIG2 image compression works. To reduce file space, the compression system looks for areas of an image that are similar and, when it finds them, makes one compressed version and reuses it across all the similar areas. Kriesel says the problem apparently only exists when using the scanner's normal, lowest-quality setting, which is the only one that uses JBIG2 compression. He notes that Xerox says the scanner's "high" and "higher" settings use a different compression system.

SIGN IN

User Name  
Password  
» Forgot Password  
» Create an Account

MORE NEWS

Rent-a-Robot Answer to L Smaller U.S. Reuters

Tech in the World  
The New York T

New Areas of Self-Organiz Andrei Sukhov et al.

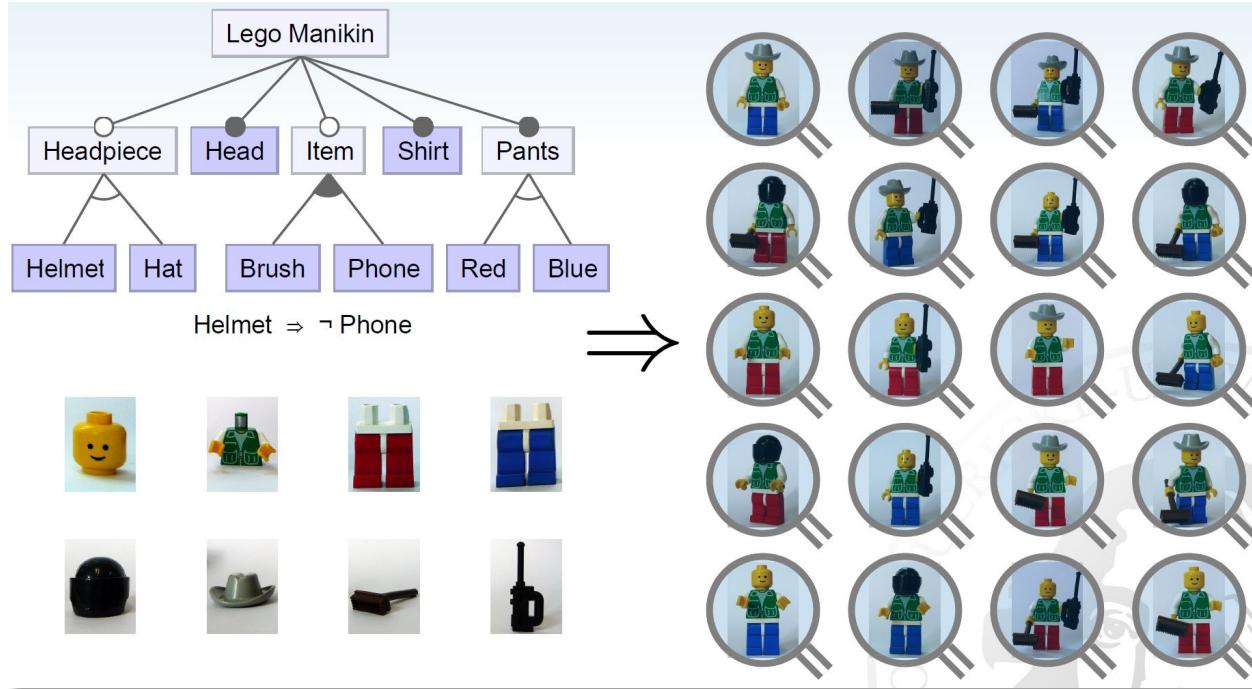
ACM RESOUR

Using Con Update Da Microsoft

Original WC 7535 WC 7556 (A) WC 7556 (B) WC 7556 (C)

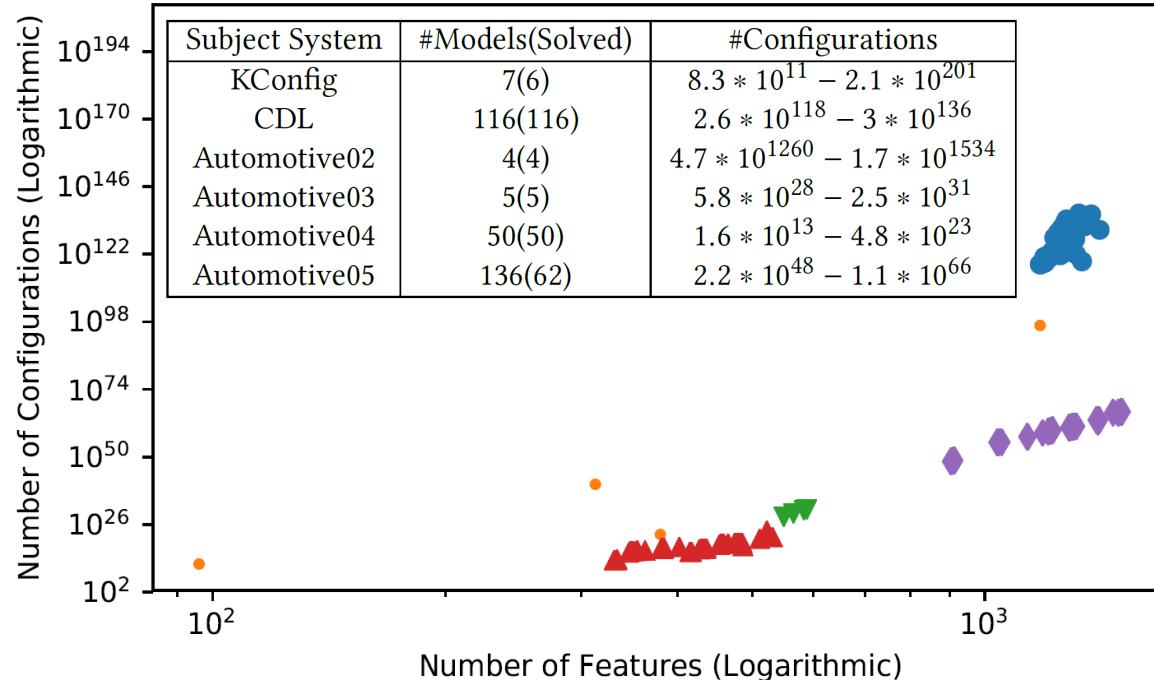

# The Brute Force Strategy to Reason About Variability

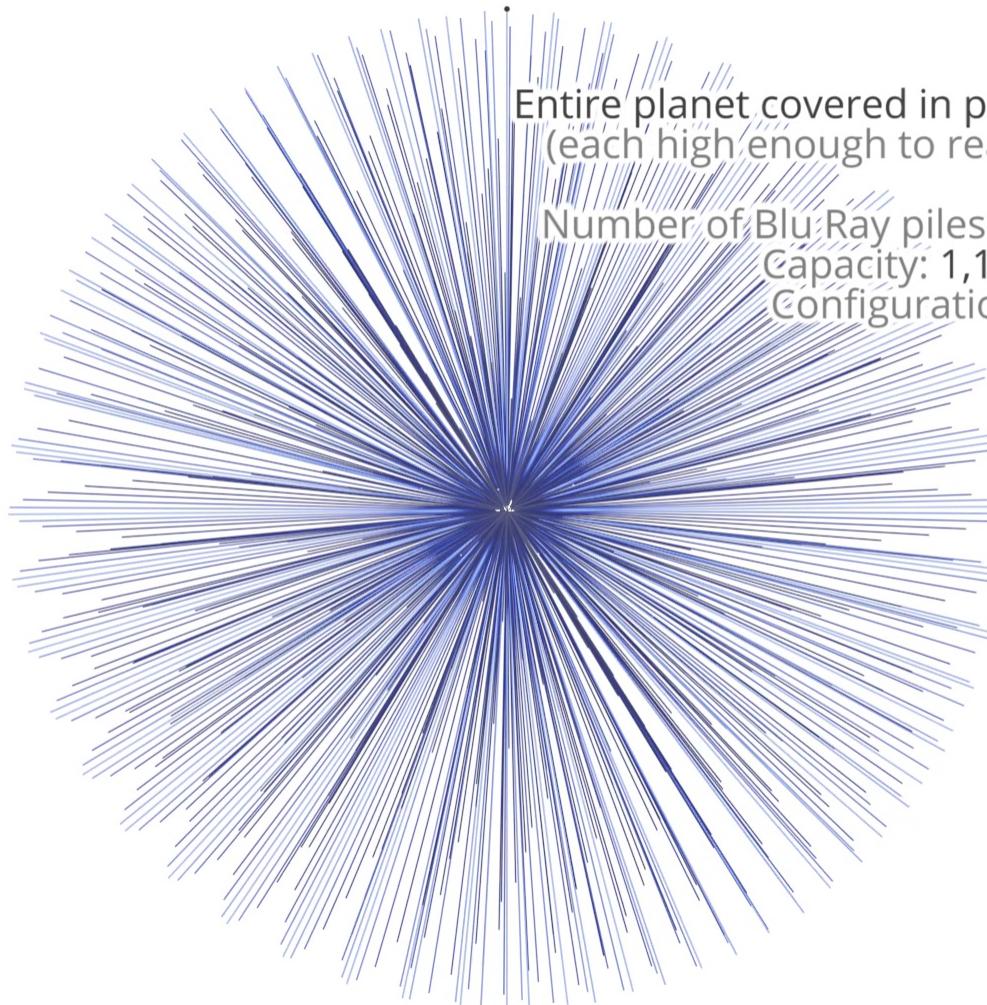
Let's enumerate all configurations and test them.



# Features Give Rise to *Many* Configurations

Sundermann et al. VaMoS'20





Entire planet covered in piles of Blu Rays  
(each high enough to reach the moon)

Number of Blu Ray piles: 35 quadrillion  
Capacity: 1,1 quadrillion YB  
Configurations:  $9,6 \times 10^{38}$

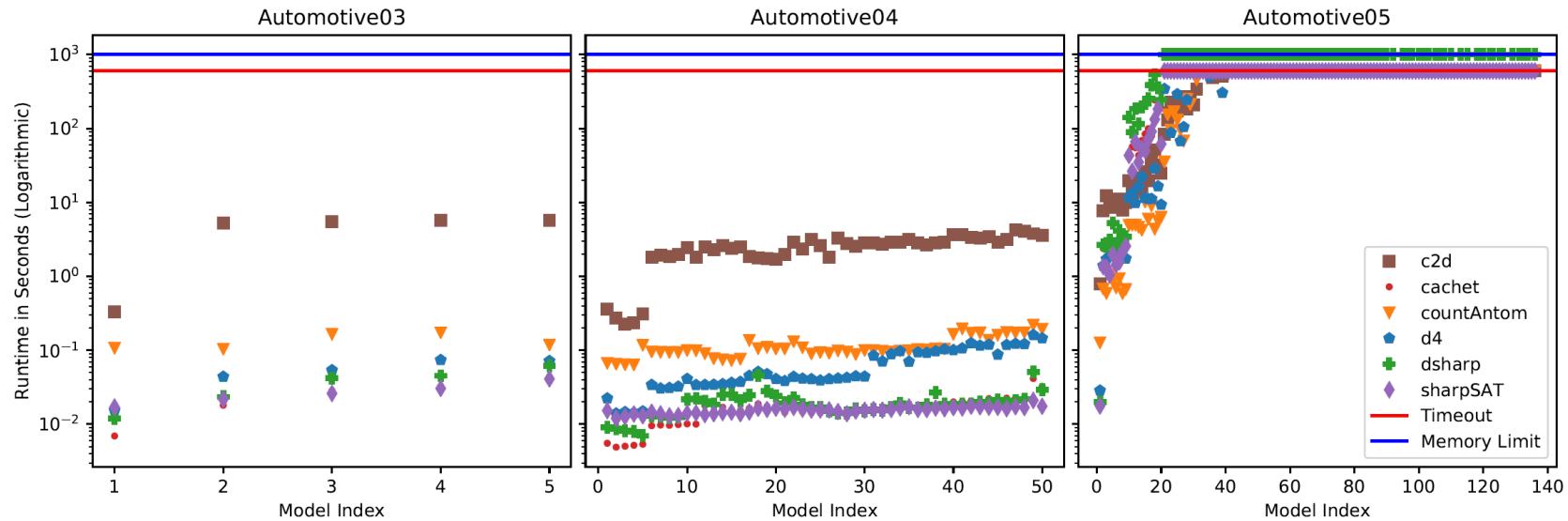
# Complexity Levels for Feature-Oriented Product Lines

(without custom development in application engineering)

1. Can you check whether there is a valid configuration? #voidfm
2. Can compute the number of configurations? #modelcounting
3. Can you enumerate all configurations? #bruteforce
4. Can you generate the sources for all products?
5. Can you compile all products?
6. Can you test all products?

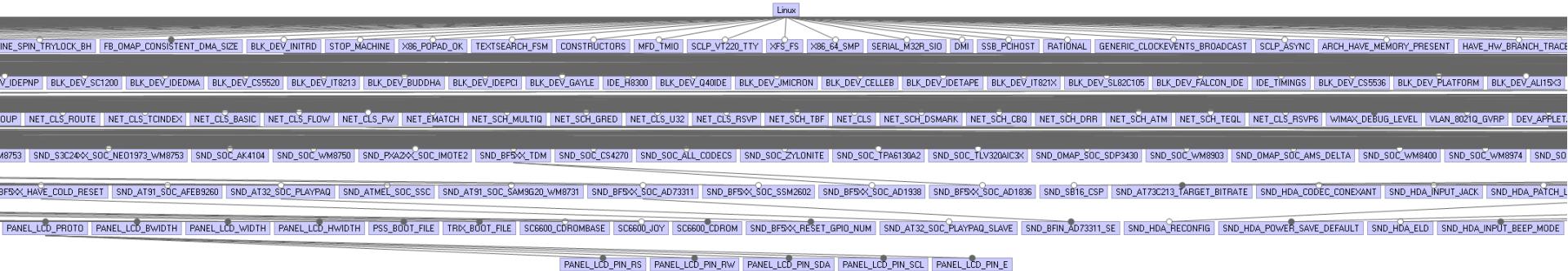
# Complexity of Product Lines Grows Over Time

Sundermann et al. VaMoS'20



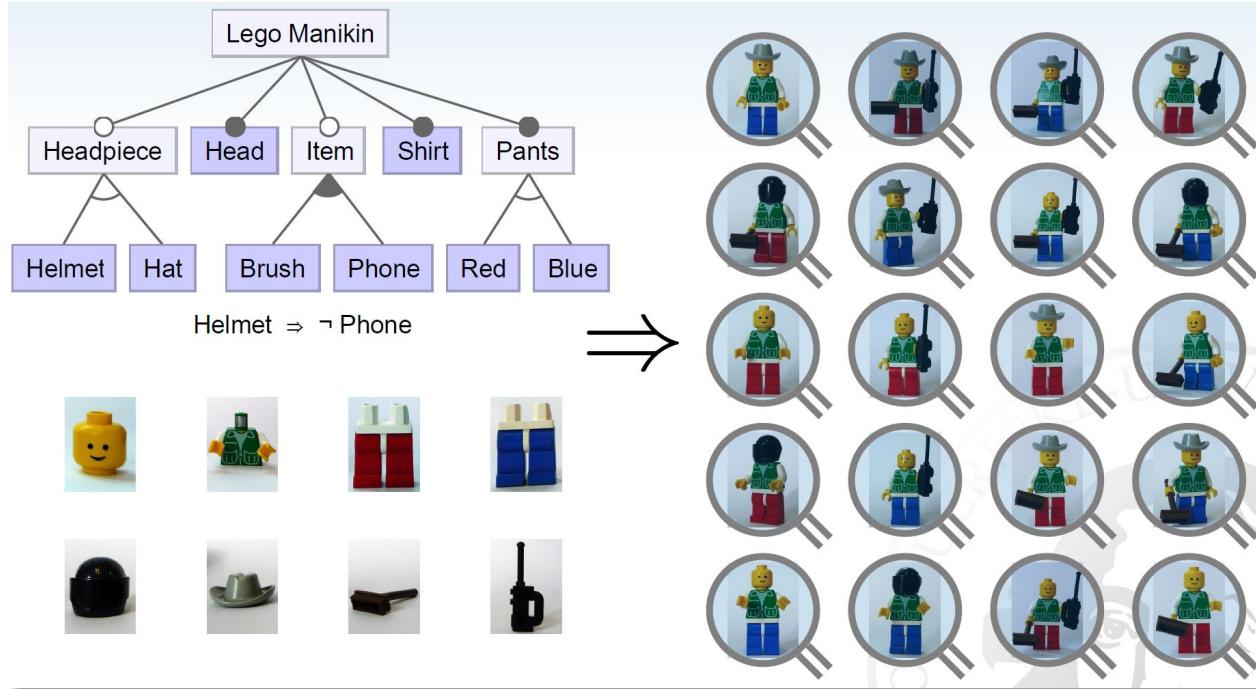
# Product Lines with Unknown Number of Configurations

Subject System	#Models(Solved)	#Configurations
KConfig	7(6)	$8.3 * 10^{11} - 2.1 * 10^{201}$
CDL	116(116)	$2.6 * 10^{118} - 3 * 10^{136}$
Automotive02	4(4)	$4.7 * 10^{1260} - 1.7 * 10^{1534}$
Automotive03	5(5)	$5.8 * 10^{28} - 2.5 * 10^{31}$
Automotive04	50(50)	$1.6 * 10^{13} - 4.8 * 10^{23}$
Automotive05	136(62)	$2.2 * 10^{48} - 1.1 * 10^{66}$



# The Brute-Force Strategy to Reason About Variability

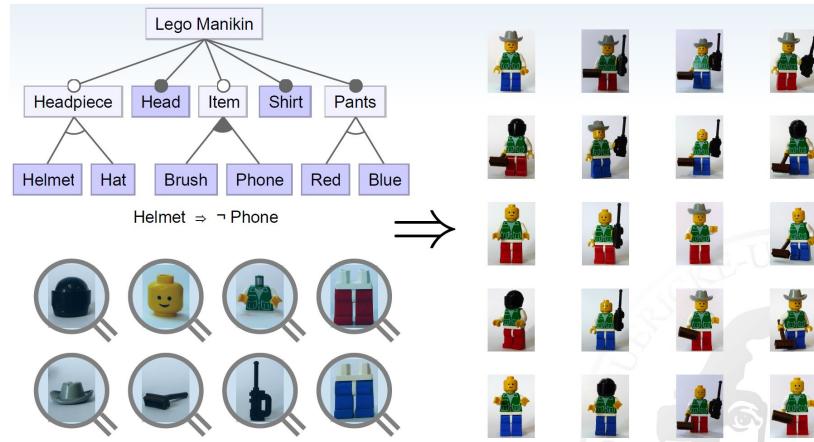
Thüm et al. CSUR'14: Unoptimized Product-Based Analysis



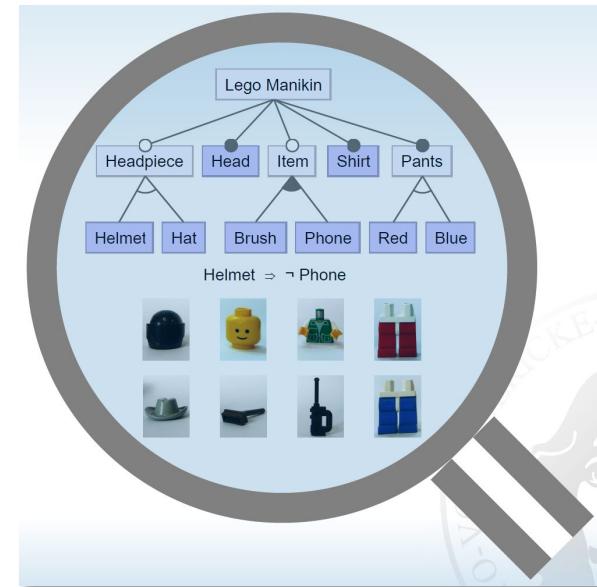
# Statically Reasoning About Variability

Thüm et al. CSUR'14

## Feature-Based Analysis



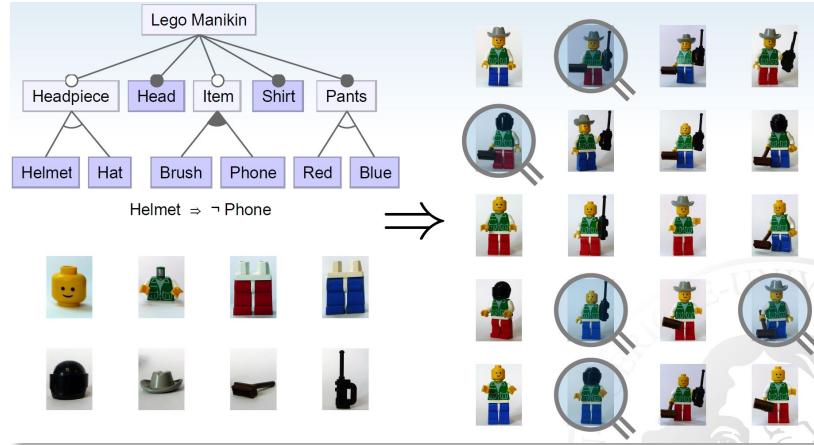
## Family-Based Analysis



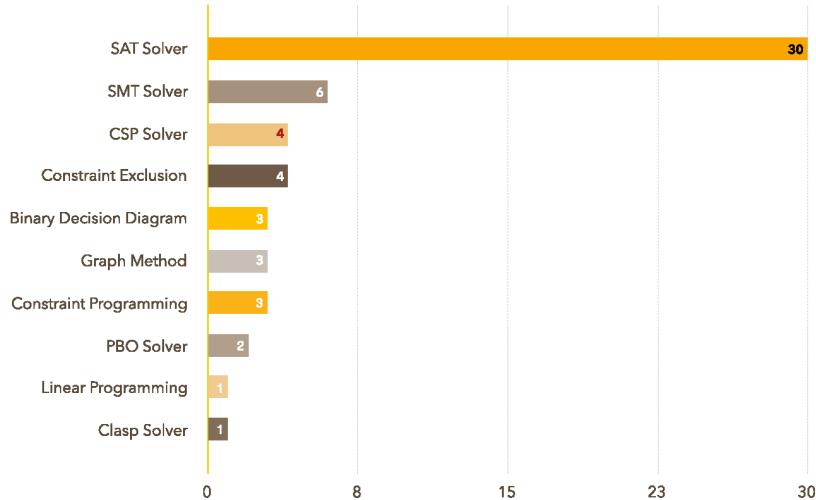
# Efficient Testing of Variability

Sample-Based Analysis

Varshosaz et al. SPLC'18

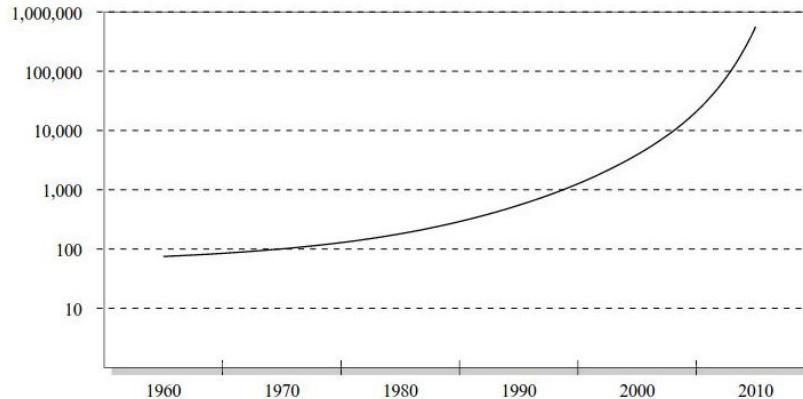


Ahmed et al. ACCESS'17



# Reasoning With Solvers: Why?

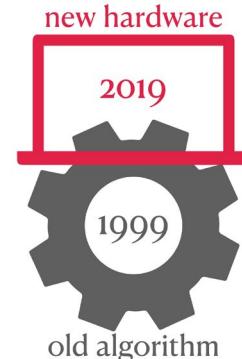
## Continuous Progress on SAT Solving



number of variables of a typical, practical SAT instance  
that can be solved by the best solvers in that decade

## The Time-Leap-Challenge

Moore's Law



Algorithm  
Development

# Efficient Reasoning About Constraints

Krieter et al. ICSE'18

## Propagating Configuration Decisions with Modal Implication Graphs

Sebastian Krieter  
University of Magdeburg, Germany  
Harz University of Applied Sciences  
Wernigerode, Germany  
sebastian.krieter@ovgu.de

Thomas Thüm  
TU Braunschweig, Germany  
t.thuem@tu-braunschweig.de

Sandro Schulze  
Reimar Schröter  
Gunter Saake  
University of Magdeburg, Germany  
sandro.schulze@ovgu.de  
reimar.schroeter@ovgu.de  
saake@iti.cs.uni-magdeburg.de

### ABSTRACT

Highly-configurable systems encompass thousands of interdependent configuration options, which require a non-trivial configuration process. Decision propagation enables a backtracking-free configuration process by computing values implied by user decisions. However, employing decision propagation for large-scale systems is a time-consuming task and, thus, can be a bottleneck in interactive configuration processes and analyses alike. We propose modal implication graphs to improve the performance of decision propagation by precomputing intermediate values used in the process. Our evaluation results show a significant improvement over state-of-the-art algorithms for 120 real-world systems.

### CCS CONCEPTS

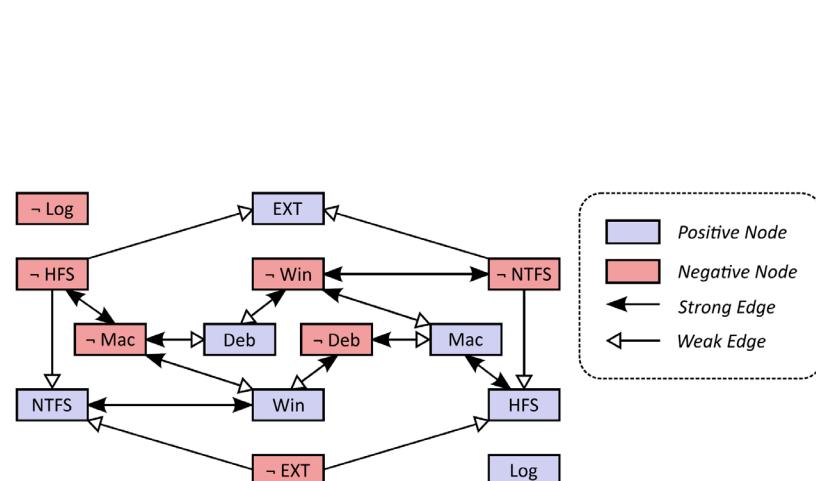
• Software and its engineering → Software product lines;

### KEYWORDS

Software product line, Configuration, Decision Propagation

### ACM Reference Format:

Sebastian Krieter, Thomas Thüm, Sandro Schulze, Reimar Schröter, and Gunter Saake. 2018. Propagating Configuration Decisions with Modal Implication Graphs. In *ICSE '18: 40th International Conference on Software Engineering*, May 27–June 3, 2018, Gothenburg, Sweden. ACM, New York, NY, USA, 12 pages. <https://doi.org/10.1145/3180155.3180159>



# How to Express Constraints?

How to express constraints?

- ~~Enumerate all valid configurations~~
- ~~Natural language~~
- ~~Compatibility matrices~~
- ~~List of rules~~
  - A and B implies C or D
- ~~Propositional logic~~
- ~~Decision models~~
- ~~Feature models~~
- ...

Desired properties of constraints?

- Machine readable
- Unambiguous
- Explicit
- Expressive
- Hierarchically organized
- Human readable #MODEVAR
- Restricted visibility
- ...

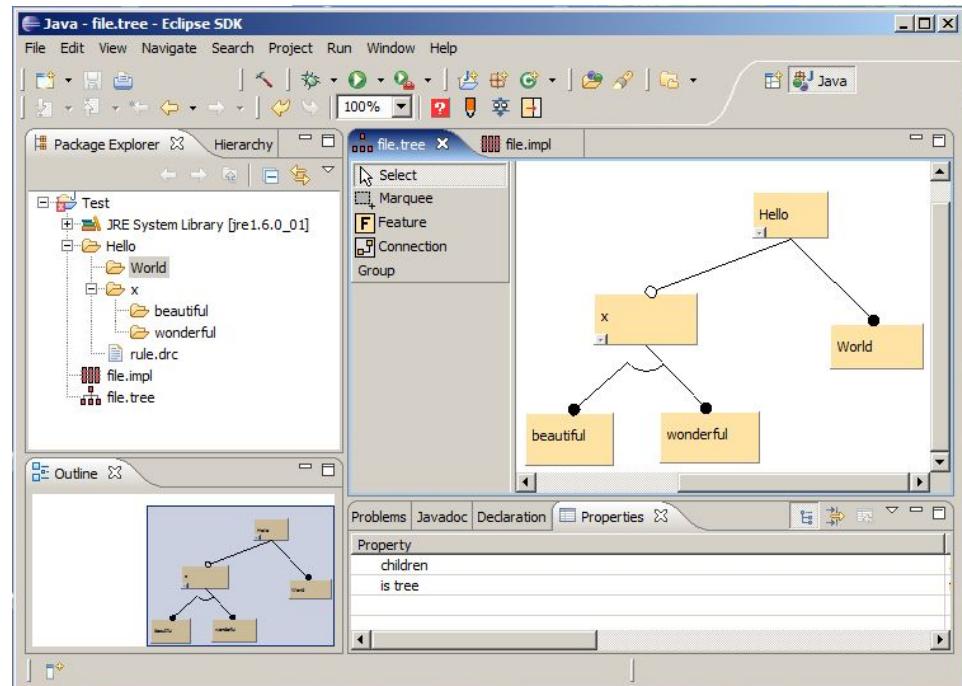
# How Is Your Research Connected to Constraints?

Breakout Rooms

# Where Is Tool Support?

Part III

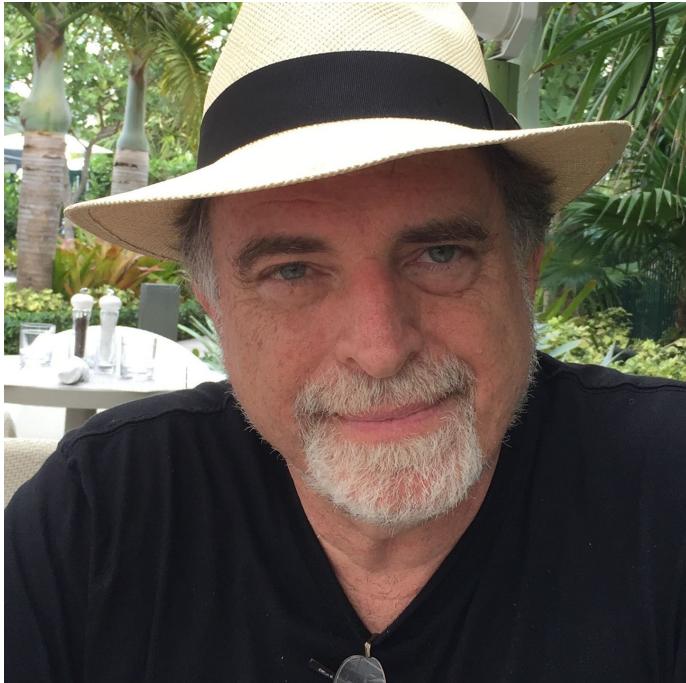
# 2007: Christian, I Need a Team Project



# Also 2007: Christian, I Need an Internship



# Still 2007: Don, Look What I've Implemented



Refactoring Feature Models using **I**DE **F**eature

First

Don Batory  
Department of Computer Science  
University of Texas at Austin  
batory@cs.utexas.edu

Christian Kästner  
School of Computer Science  
University of Magdeburg  
kaestner@iti.cs.uni-magdeburg.de

Thomas Thüm  
Department of Computer Science  
University of Texas at Austin  
tthuem@cs.utexas.edu

**ABSTRACT**  
...

**Categories and Subject Descriptors**  
H.4 [Information Systems Applications]: Miscellaneous;  
D.2.8 [Software Engineering]: Metrics—complexity measures, performance measures

**General Terms**  
...

**Keywords**  
Refactoring Product Lines, Feature Diagrams, FeatureIDE

**1. INTRODUCTION**

**2. FEATURE DIAGRAMS**

A Feature Model simply consists of a GUIDSL grammar and a set of crosscutting constraints. The latter can be given due to a set of propositional formula. A GUIDSL grammar specifies an ordering of the features and a set of propositional formula, too [2].

A GUIDSL grammar has a graphical representation known as Feature Diagram (FD). Because there are many definitions of FDs, we will summarize the characteristics of the examined FDs.

A feature is either a compound feature or a layer. Lay-

Figure 1: Connection types at the feature diagram

As we mentioned above every FD implies a set of propositional formula. Each of the structures in Figure 1 belongs to  $A \vee B \vee Y \Rightarrow X$  and

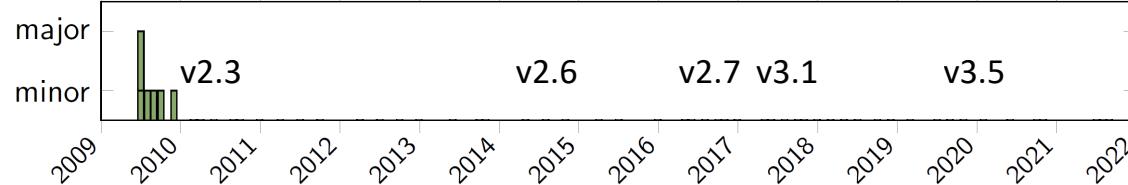
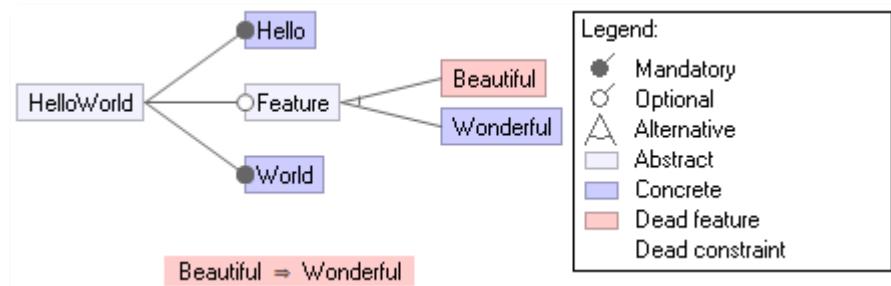
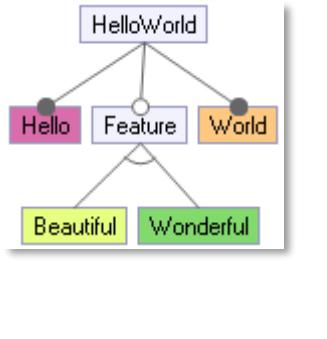
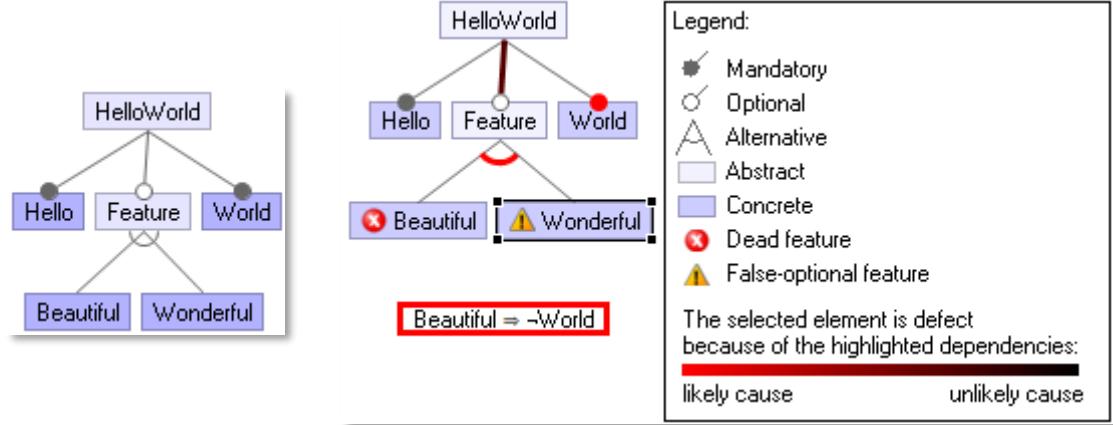
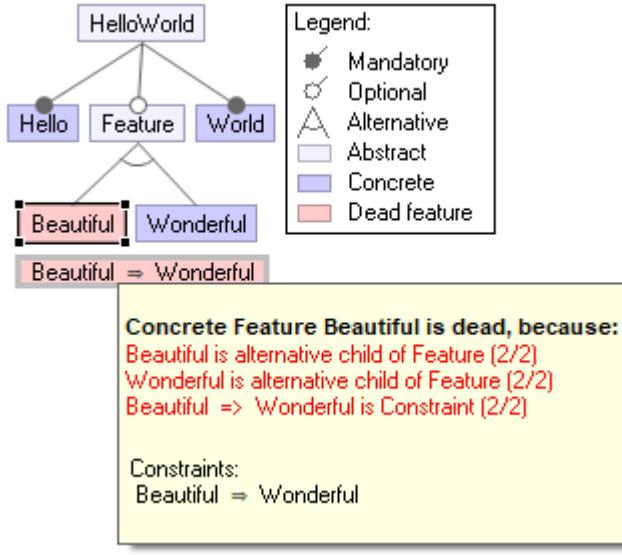
- $X \Rightarrow A \wedge B$  (AND),
- $X \Rightarrow A \vee B \vee Y$  (OR), and
- $X \Rightarrow A \oplus B \oplus Y$  (EXOR).

FeatureIDE uses Feature Diagrams not only for visualization, but also to manipulate the grammar. Therefore we will discuss editings on FDs in the next section.

**3. EDITING FEATURE DIAGRAMS**

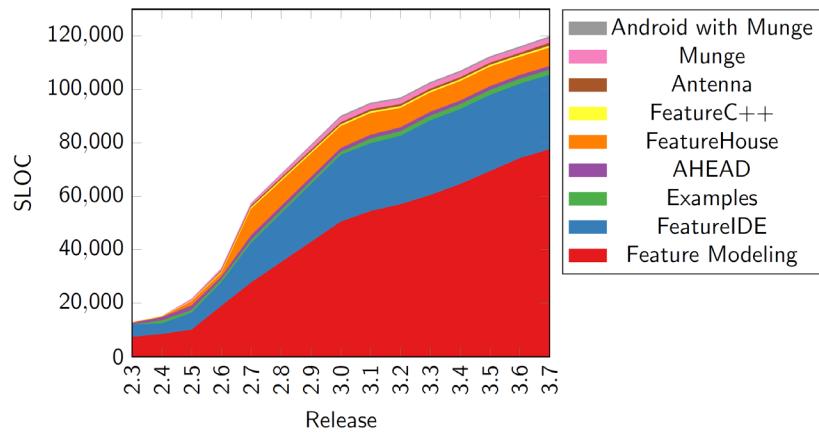
There are several ways how you can change the Software Product Line (SPL) by editing the FD:

1. adding a layer to a set of products
2. removing a layer from a set of products

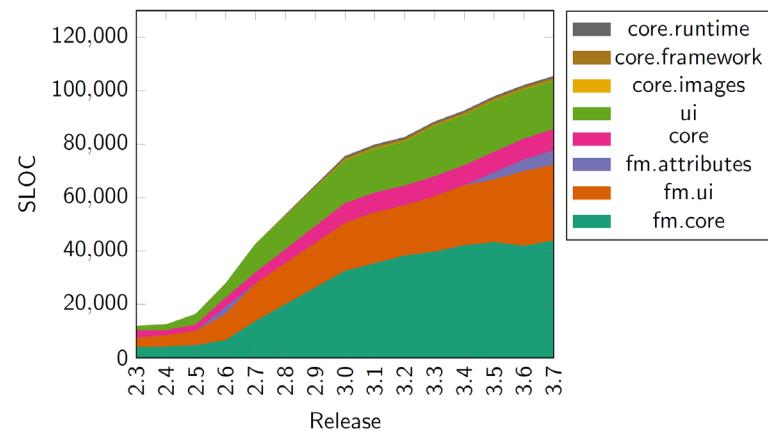


# The Size of FeatureIDE Over Time

Installable Eclipse Features



Main Plug-Ins



# FeatureIDE Support Requests

2021



# FeatureIDE Book

Published 2017 with 10+ years of experience



# Current & Former Contributors

- [Thomas Thüm](#) (University of Ulm, Germany)
- [Sebastian Krieter](#) (Harz University of Applied Sciences, Germany)
- [Chico Sundermann](#) (University of Ulm, Germany)
- [Tobias Heß](#) (University of Ulm, Germany)
- [Elias Kuiter](#) (University of Magdeburg, Germany)
- [Rahel Arens](#) (University of Ulm, Germany)
- [Kevin Jedelhauser](#) (University of Ulm, Germany)
- [Johannes Herschel](#) (University of Ulm, Germany)
- [Benedikt Jutz](#) (University of Ulm, Germany)
- [Thomas Leich](#) (Metop Research Institute, Germany; Harz University)
- [Gunter Saake](#) (University of Magdeburg, Germany)
- [Ina Schaefer](#) (TU Braunschweig, Germany)

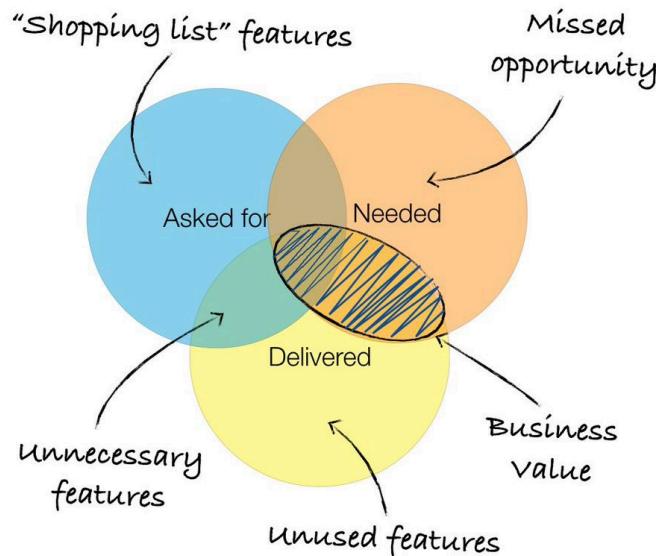
# SoftVarE Working Group

Software. Variability. Evolution.



# Recommendation for Tool Developers: Choose Features Wisely

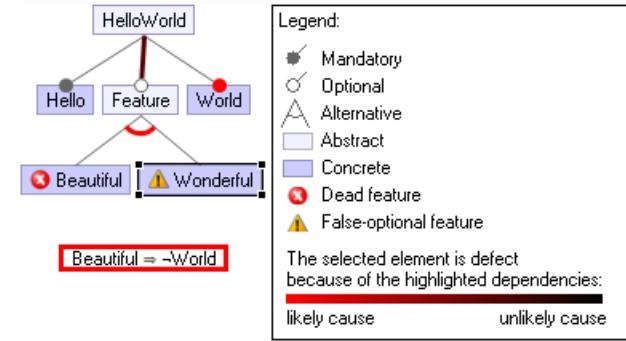
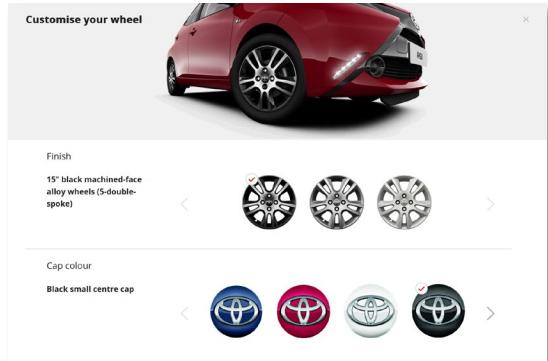
John Ferguson Smart (2017)



John Carmack (born 1970)

“The important point is that the cost of adding a feature isn’t just the time it takes to code it. The cost also includes the addition of an obstacle to future expansion. [...] The trick is to pick the features that don’t fight each other.” [\[uci.edu\]](http://uci.edu)

# Where Are My Constraints and What Do They Constrain?



# Backup Slides

# Constraints in Web Configurators: BMW

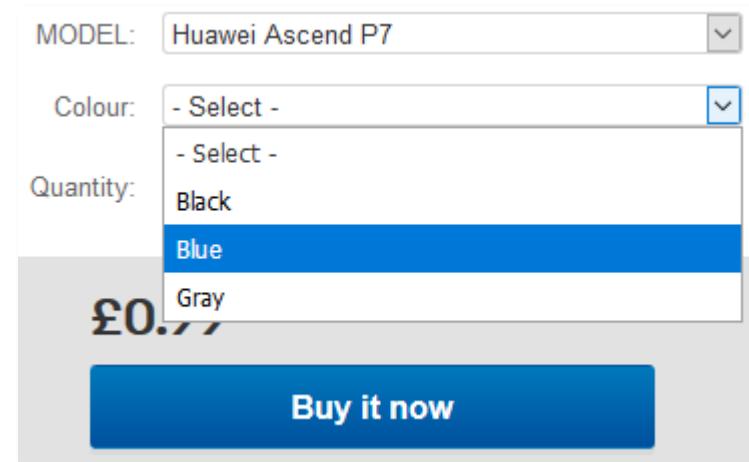
Thüm et al. CONFWS'18

Configuration Assistant.	
<a href="#">Show instructions</a>	
Your most recent action requires your configuration to be adjusted.	
Your choice	Price
+ Enhanced Bluetooth telephone with USB & Voice Control	+ £ 350.00
Adding	
+ BMW Navigation	£ 0.00
Removing	
- Enhanced Bluetooth with wireless charging	- £ 395.00
- Navigation system Professional	£ 0.00
- WiFi hotspot preparation	£ 0.00
- Media package - Professional	- £ 900.00
- Online Entertainment	£ 0.00
- Microsoft Office 365	- £ 150.00

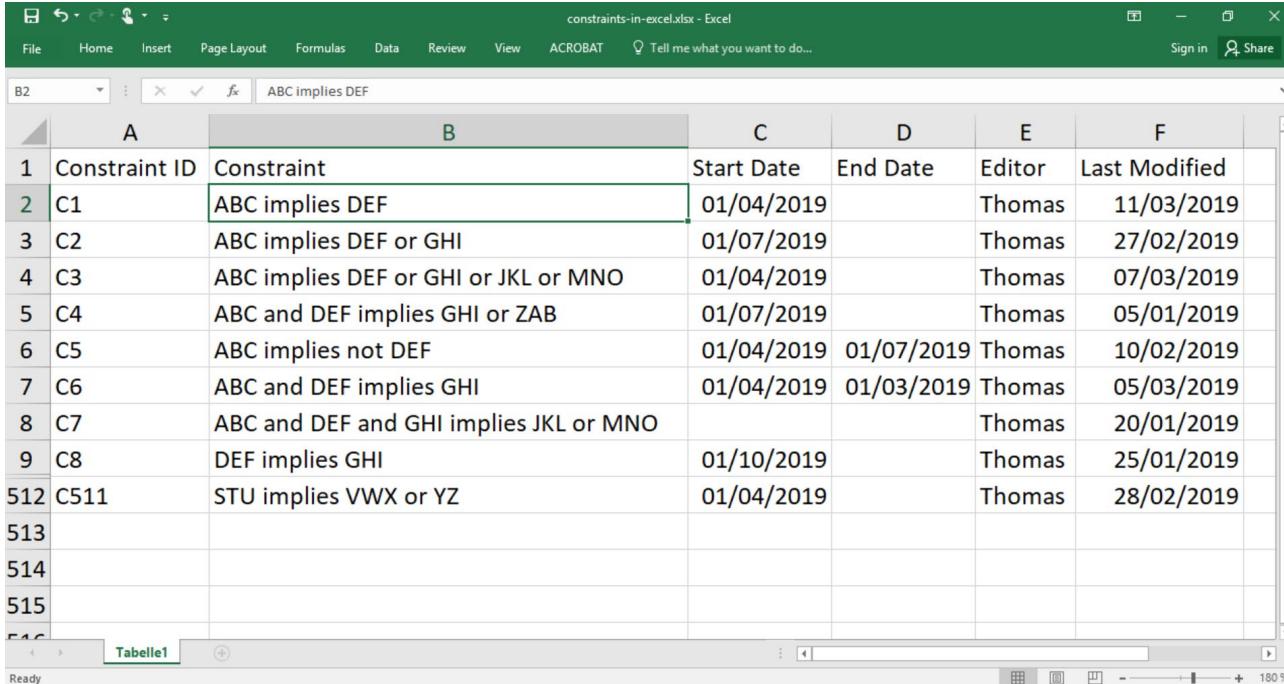
# Constraints in Web Configurators (and Selectors)

Thüm et al. CONFWS'18

	Strategy	BMW	Toyota	Lenovo	Microsoft	Amazon	Ebay	...
Default Configuration	y	y	y	y/n	y	n		
Hiding Invalid Combinations	n	y	n	n	n	y		
Automatic Deselection in Alternatives	y	y	y	y	y	y		
Alternatives of Compound Options	y	y	y	y	n	n		
Continuing with Invalid States	n	y	y	n	n	n		
Subsequent Configuration Steps	y	y	n	n	n	n		
Automated Reconfiguration	y	y	n	y/n	y	n		
Interactive Resolution of Conflicts	n	y	n	n	n	n		
	...							



# Constraints as List of Rules in Excel



The screenshot shows a Microsoft Excel spreadsheet titled "constraints-in-excel.xlsx - Excel". The table has columns labeled A through F. Column A is "Constraint ID", column B is "Constraint", column C is "Start Date", column D is "End Date", column E is "Editor", and column F is "Last Modified". The data includes:

	A	B	C	D	E	F
1	Constraint ID	Constraint	Start Date	End Date	Editor	Last Modified
2	C1	ABC implies DEF	01/04/2019		Thomas	11/03/2019
3	C2	ABC implies DEF or GHI	01/07/2019		Thomas	27/02/2019
4	C3	ABC implies DEF or GHI or JKL or MNO	01/04/2019		Thomas	07/03/2019
5	C4	ABC and DEF implies GHI or ZAB	01/07/2019		Thomas	05/01/2019
6	C5	ABC implies not DEF	01/04/2019	01/07/2019	Thomas	10/02/2019
7	C6	ABC and DEF implies GHI	01/04/2019	01/03/2019	Thomas	05/03/2019
8	C7	ABC and DEF and GHI implies JKL or MNO			Thomas	20/01/2019
9	C8	DEF implies GHI	01/10/2019		Thomas	25/01/2019
512	C511	STU implies VWX or YZ	01/04/2019		Thomas	28/02/2019
513						
514						
515						
516						

# Uniform Modeling of Constraints

Presented on Friday

## Yet Another Textual Variability Language? A Community Effort Towards a Unified Language

Chico Sundermann  
University of Ulm  
Ulm, Germany  
chico.sundermann@uni-ulm.de

Kevin Feichtinger  
LIT CPS Lab  
Johannes Kepler University Linz  
Linz, Austria  
kevin.feichtinger@jku.at

Rick Rabiser  
CDL VaSiCS, LIT CPS Lab  
Johannes Kepler University Linz  
Linz, Austria  
rick.rabiser@jku.at

Dominik Engelhardt  
TU Braunschweig  
Braunschweig, Germany  
d.engelhardt@tu-bs.de

Thomas Thüm  
University of Ulm  
Ulm, Germany  
thomas.thuem@uni-ulm.de

### ABSTRACT

Variability models are commonly used to model commonalities and variability in a product line. There is a large variety of textual formats to represent and store variability models. This variety causes overhead to researchers and practitioners as they frequently need to translate models. The MODEVAR initiative consists of dozens of researchers and aims to find a unified language for variability modeling. In this work, we describe the cooperative development of a textual variability language. We evaluate preferences of the community regarding properties of existing formats and applications for an initial design of a unified variability language. Then, we examine the acceptance of the community for our proposal. The results indicate that our proposal is a promising start towards a unified variability language instead of *yet another language*. We envision that the community applies our language proposal in teaching, research prototypes, and industrial applications to further evolve the design and then ultimately reach a unified language.

*Systems and Software Product Line Conference - Volume A (SPLC '21), September 6–11, 2021, Leicester, United Kingdom. ACM, New York, NY, USA, 12 pages. <https://doi.org/10.1145/3461001.3471145>*

### 1 INTRODUCTION

Product lines are widely used to manage families of similar products [14]. Variability models are common to specify constraints of a product line. However, there are different types of variability models, such as feature models and decisions models. The literature also considers a large variety of textual representations to describe variability models [1, 3, 4, 6, 9, 22, 23, 27, 41, 44, 49, 55, 59, 60, 76]. Furthermore, existing tools typically depend on specific formats [3, 15, 44, 49, 78]. Working with a multitude of formats induces large additional effort for practitioners and researchers. Using a variability model that is stored in a different format requires implementing a parser first. For example, if a specific capability (e.g., to analyze a model) is only available in a particular tool, variability models need to be converted and mapped to the specific tool's internal representation.

### features

```
Server {abstract}  
mandatory  
FileSystem  
or // with cardinality: [1..*]  
NTFS  
APFS  
EXT4
```

### OperatingSystem {abstract}

```
alternative  
Windows  
macOS  
Debian
```

### optional

```
Logging {  
default,  
log_level "warn" // Feature Attribute  
}
```

### constraints

```
Windows => NTFS  
macOS => APFS
```