



Technische  
Universität  
Braunschweig



# On Language Levels for Feature Modeling Notations

Thomas Thüm, Christoph Seidl, Ina Schaefer  
MODEVAR, September 10, 2019

## Part I

# The Need for Variability Modeling



# The Situation 110 Years Ago: Ford Model T



„Any customer can have a car painted any color that he wants so long as it is black.“

— Henry Ford, 1909

# Today: Every Second Car has a Unique Configuration



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# Constraints Among Features are Challenging

Configuration Assistant.

➤ Show instructions

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 Among Features are Challenging

Configuration Assistant.

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Your choice	Price
+ Enhanced Bluetooth telephone with USB & Voice Control	+ £ 350.00
<hr/>	
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- Media package - Professional	- £ 900.00
- Online Entertainment	£ 0.00
- Microsoft Office 365	- £ 150.00

A car without Microsoft Office 365?!?

# Constraints Among Features are Challenging

## Display

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

SELECTED

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

+ £159.60

Please note this display is only available with WWAN/mobile broadband.

# Constraints Among Features are Challenging

Display

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

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Please note this display is only available with WWAN/mobile broadband.

Invalid configuration!

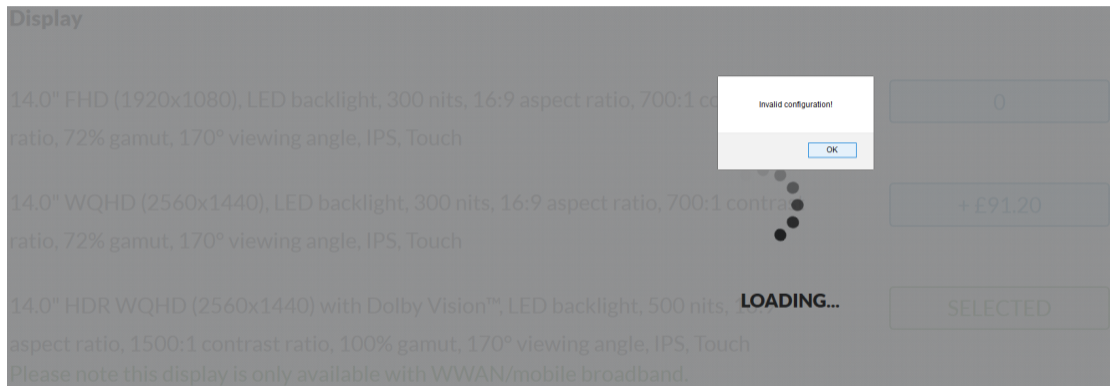
OK

0

+ £91.20

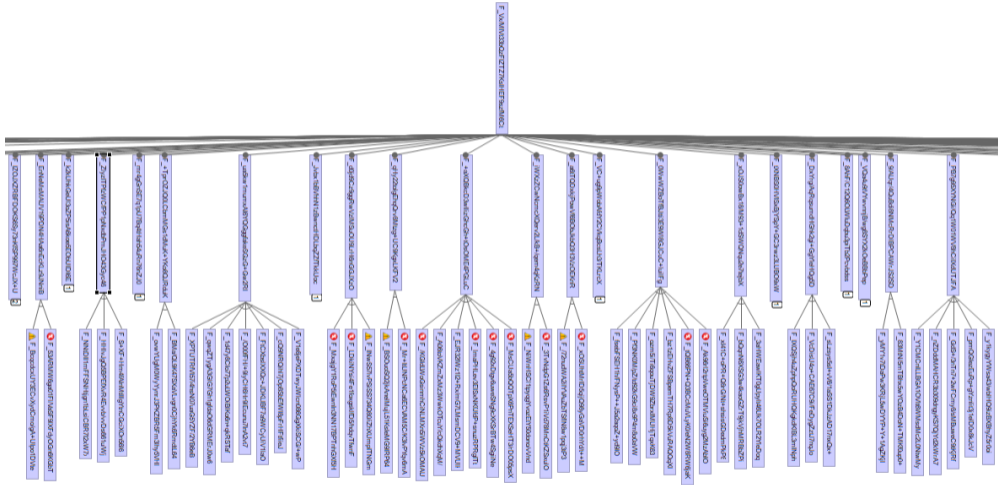
LOADING...

SELECTED





# Variability Models as Central Knowledge Database

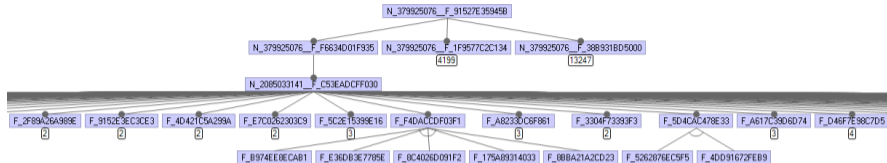


## Part II

# The Need for Variability Analyses



# Real-World Variability Modeling

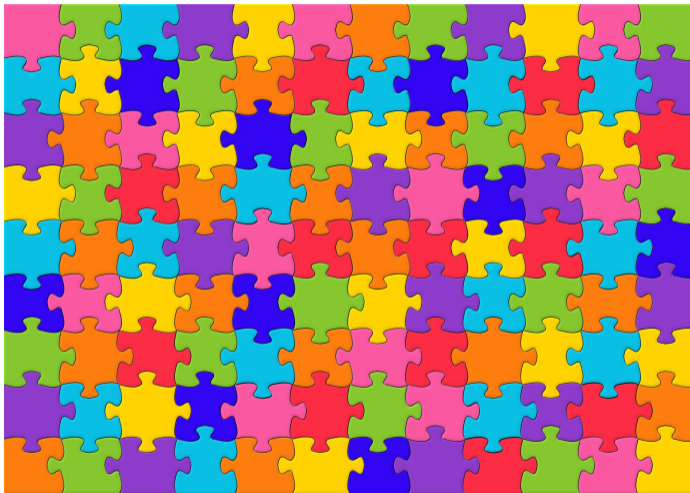


F\_6B23DD66CE4C ⇒ F\_287D032B6EC5  
F\_75372381F32E ⇒ F\_8A42FBF6E175  
F\_A82330C6F861 ∧ (F\_E528E7186064 ∨ F\_536DAEEFC371 ∨ F\_AD9CAB8377D4) ⇒ F\_1587476818FF  
F\_A4FD6038241E ∧ L\_2163186830\_F\_31B7538F7682 ⇒ F\_A62329B1F858  
F\_BF6BEE85A1D3 ∧ L\_108785184\_F\_AEF4FD38D98 ∧ F\_FDEACBEC906 ⇒ F\_7A7F1EBFAFDC  
F\_0A7FB52A4A78 ∧ L\_3491892541\_F\_787E2906DD02 ⇒ F\_29CFF8E598E4  
F\_BFC87325974 ∧ L\_3441900933\_F\_E0A4648BDABC ∧ F\_FDEACBEC906 ∨ F\_BF6BEE85A1D3 ∧ L\_108785184\_F\_AEF4FD38D98 ∧ F\_A6909BC6DCB ⇒ F\_DF3980952E2

⋮

- Thousands of features and constraints, increases over time
- No modularity or information hiding
- Temporal elements
- Typically not modeled with feature models

# One Product Line Specified with Different "Languages"



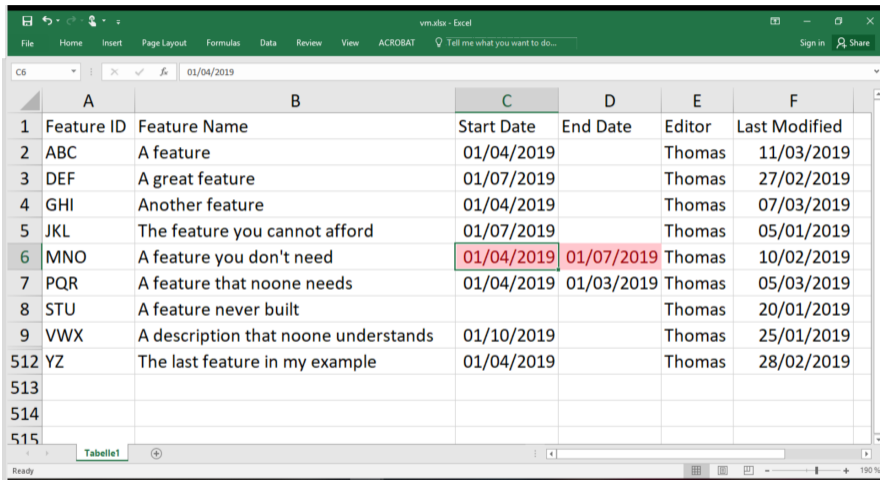
Thomas Thüm | On Language Levels for Feature Modeling Notations | Slide 10

# Variability Modeling par Excellence

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D	E	F
1	Feature ID	Feature Name	Start Date	End Date	Editor	Last Modified
2	ABC	A feature	01/04/2019		Thomas	11/03/2019
3	DEF	A great feature	01/07/2019		Thomas	27/02/2019
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8	STU	A feature never built			Thomas	20/01/2019
9	VWX	A description that noone understands	01/10/2019		Thomas	25/01/2019
512	YZ	The last feature in my example	01/04/2019		Thomas	28/02/2019
513						
514						
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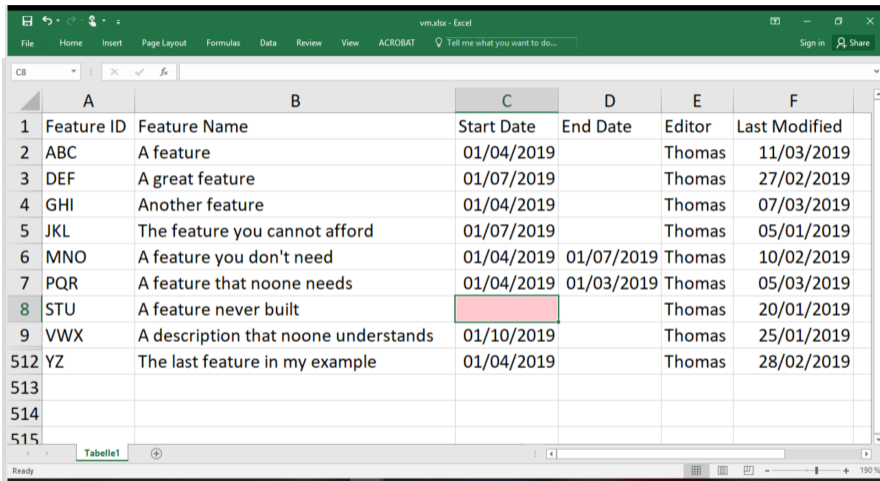
# Variability Modeling par Excellence



The screenshot shows an Excel spreadsheet with the following data:

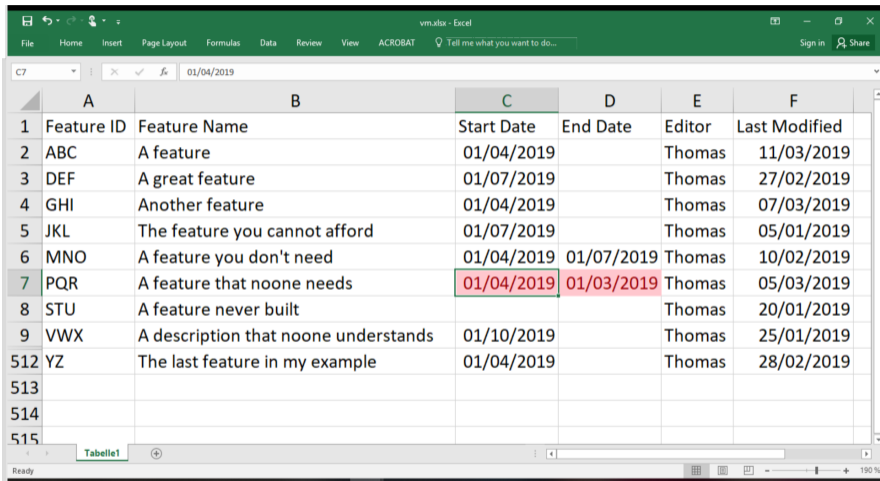
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# Variability Modeling par Excellence

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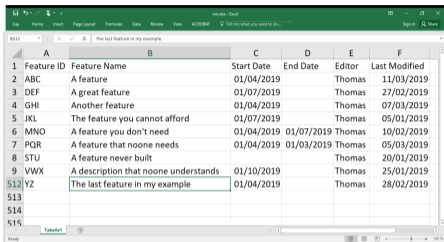
	A	B	C	D	E	F
1	Constraint ID	Constraint	Start Date	End Date	Editor	Last Modified
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5	C4	ABC and DEF implies GHI or ZAB	01/07/2019		Thomas	05/01/2019
6	C5	ABC implies not DEF	01/04/2019	01/07/2019	Thomas	10/02/2019
7	C6	ABC and DEF implies GHI	01/04/2019	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						
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# Variability Modeling par Excellence

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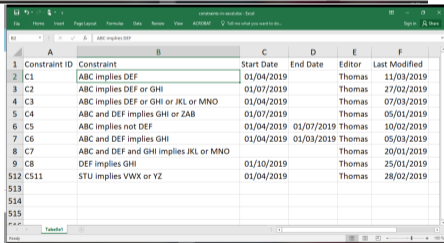
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# Clone-and-Own of Variability Models



The screenshot shows an Excel spreadsheet with a table of features. The table has columns for Feature ID, Feature Name, Start Date, End Date, Editor, and Last Modified. The data is as follows:

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variability\_model - Excel

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constraints-in-variability - Excel

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# Anomalies in Variability Models

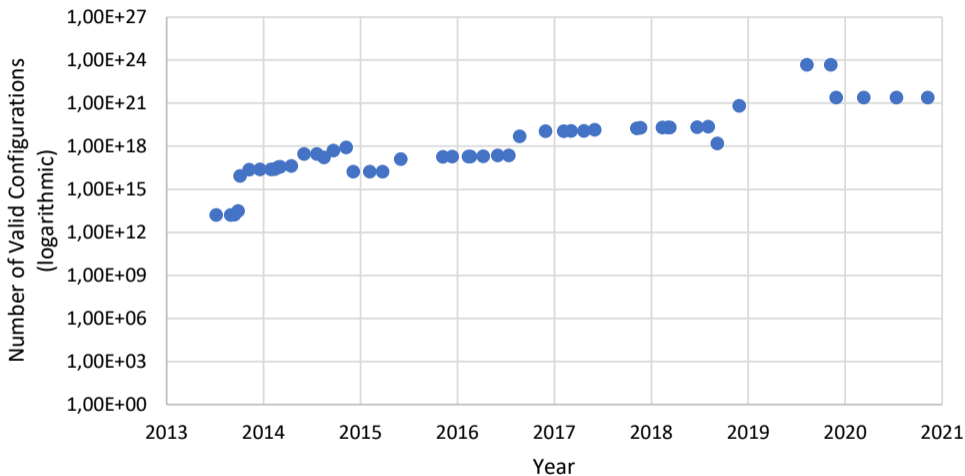


# Anomalies in Variability Models



- F\_Y1CMcNLLBGA1OVNBWmsdMc2L0NwMy - F\_sqtTaBKM6URDZ9898qLUUeGpPvA3
- F\_rq+PRxLaaPu4WwH+8PQzwMzXoKfVh5 - F\_4g92xDtgy6uwsSng9cXKSrBTW4SgiNe - F\_JmaPHLev3EiSxKJfPd+snuZRPRgTl - F\_AI
- F\_7JvNktsJ48BEQMFJAj82M7avfheZm+D - F\_mHq7muGhXh1+5mciQ2C3X0oeIU00
- F\_yN5jxMoss6YHcAYVKZfW3V414CHWtbsp - F\_e26xkDTqCYhS78m76ENRiCl18reC7
- F\_yN5jxMoss6YHcAYVKZfW3V414CHWtbsp - F\_yfshNfaB6U6gOXBWb0aZxqf4RKUjGE
- F\_IWcNo1CBknKRegXeF710BwYyicwQlgtf - F\_yfshNfaB6U6gOXBWb0aZxqf4RKUjGE - F\_mHq7muGhXh1+5mciQ2C3X0oeIU00
- F\_IWCNo1CBknKRegXeF710BwYyicwQlgtf - F\_e26xkDTqCYhS78m76ENRiCl18reC7
- F\_Q4S+3nTn+2wFcmY8i8MBuwcC9IKRf - F\_nqndJexpxzLYRd03kQFb+1sFolcBM8b - F\_QBdGXKignTQw4Fz2pTvg35LIVGfGAM
- F\_nZDd6MAHCR3b309dngyK5TQYd2kWA7 - F\_nqndJexpxzLYRd03kQFb+1sFolcBM8b - F\_QBdGXKignTQw4Fz2pTvg35LIVGfGAM
- F\_Y1CMcNLLBGA1OVNBWmsdMc2L0NwMy - F\_nqndJexpxzLYRd03kQFb+1sFolcBM8b - F\_QBdGXKignTQw4Fz2pTvg35LIVGfGAM
- F\_nZDd6MAHCR3b309dngyK5TQYd2kWA7 - F\_nqndJexpxzLYRd03kQFb+1sFolcBM8b
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- F\_Q4S+3nTn+2wFcmY8i8MBuwcC9IKRf - F\_zv0Ym6vHwHr8V+G1JlUoPhq96gJ - F\_wH0aBDhEURROXpGpCk1oBWSGLpxRN
- F\_nZDd6MAHCR3b309dngyK5TQYd2kWA7 - F\_zv0Ym6vHwHr8V+G1JlUoPhq96gJ - F\_wH0aBDhEURROXpGpCk1oBWSGLpxRN
- F\_Y1CMcNLLBGA1OVNBWmsdMc2L0NwMy - F\_zv0Ym6vHwHr8V+G1JlUoPhq96gJ - F\_wH0aBDhEURROXpGpCk1oBWSGLpxRN
- F\_GdS+3nTn+2wFcmY8i8MBuwcC9IKRf - F\_zv0Ym6vHwHr8V+G1JlUoPhq96gJ
- F\_nZDd6MAHCR3b309dngyK5TQYd2kWA7 - F\_zv0Ym6vHwHr8V+G1JlUoPhq96gJ
- F\_Y1CMcNLLBGA1OVNBWmsdMc2L0NwMy - F\_zv0Ym6vHwHr8V+G1JlUoPhq96gJ
- F\_OvFgyUXNnzT4BEg6amG44bQKpmeT - F\_ZB9Eg1pkiGR8Bb1nHrV4na2DZyBD - F\_J82dWRC00NwauJmXGX0C033p4y95s
- F\_zEFYzUcChpPp9i3ZHR2zGX0CMjZ - ~{F\_UGPDvPXqGYvaGadeIwzEjy+WPXMM9e}
- F\_SkagMYjNj9h6Mw4ZBjrd23jgUmx - ~{F\_UGPDvPXqGYvaGadeIwzEjy+WPXMM9e}
- F\_yOv3m0zVbVz6Zln7xq4yEPqQ1w1be - ~{F\_UGPDvPXqGYvaGadeIwzEjy+WPXMM9e}
- F\_MrDhLcCqkPAEXnKjH5AC7Uirgan - F\_9FPooQ4gEXih8S0q6585kyMz4ID5Ab
- F\_9FPooQ4gEXih8S0q6585kyMz4ID5Ab - F\_MrDhLcCqkPAEXnKjH5AC7Uirgan
- F\_1nBN1z4m6n2UTYoE88HQRlGMS1bM - F\_MrDhLcCqkPAEXnKjH5AC7Uirgan
- F\_y1kgyYWsa43w6h08eQzBhyZ5f0ai - F\_ZmGm31byvWAhLZuvkyFY8lKcV
- F\_pmQGieZuRq+ymZl3j1eD06xKJcV - F\_ZmGm31byvWAhLZuvkyFY8lKcV
- F\_GdS+3nTn+2wFcmY8i8MBuwcC9IKRf - F\_ZmGm31byvWAhLZuvkyFY8lKcV

# Configuration Spaces Tend to Grow Over Time



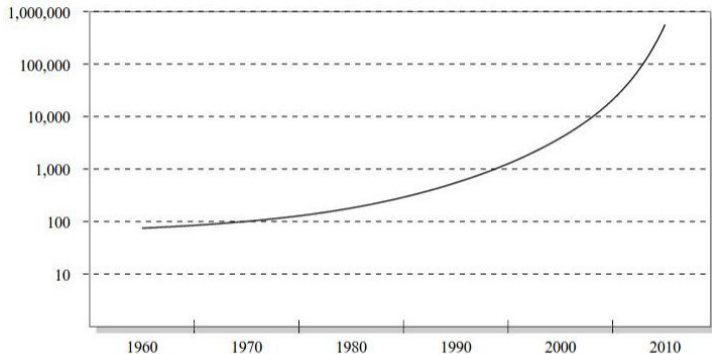
## Part III

# Criteria for Language Design





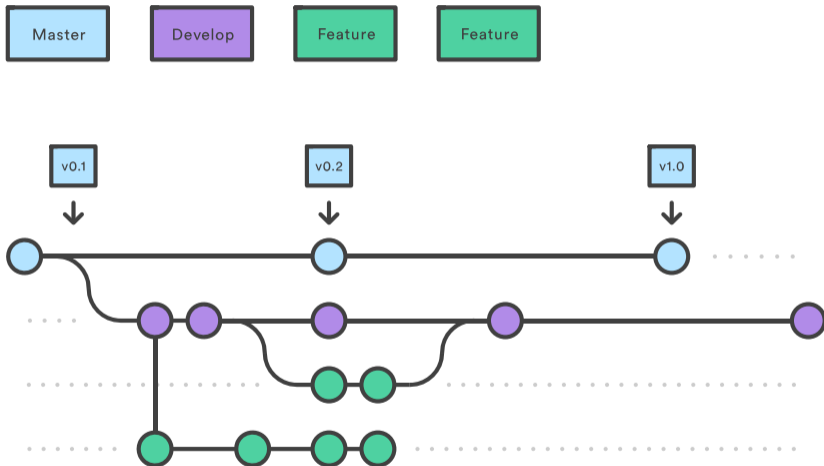
# Why to Use SAT Solvers for Variability Analysis?



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



# Industry Demands for Modularity and Branching



# Language Levels for Feature Modeling Notations

Major Levels: expressiveness aligns with solver classes

- propositional logic: SAT, binary decision diagram (BDD), #SAT, ...
- first-order logic: satisfiable modulo theory (SMT), constraint satisfaction problem (CSP)?, ...
- more needed? answer set programming (ASP)? pseudo-boolean satisfiability (PB-SAT)? ...

# Language Levels for Feature Modeling Notations

Major Levels: expressiveness aligns with solver classes

- propositional logic: SAT, binary decision diagram (BDD), #SAT, ...
- first-order logic: satisfiable modulo theory (SMT), constraint satisfaction problem (CSP)?, ...
- more needed? answer set programming (ASP)? pseudo-boolean satisfiability (PB-SAT)? ...

Minor Levels: differing expressiveness within major levels

- align with expressiveness of state-of-the-art languages
- meet requirements from typical application domains
- example: supported tree and cross-tree constraints

# Language Levels for Feature Modeling Notations

Major Levels: expressiveness aligns with solver classes

- propositional logic: SAT, binary decision diagram (BDD), #SAT, ...
- first-order logic: satisfiable modulo theory (SMT), constraint satisfaction problem (CSP)?, ...
- more needed? answer set programming (ASP)? pseudo-boolean satisfiability (PB-SAT)? ...

Minor Levels: differing expressiveness within major levels

- align with expressiveness of state-of-the-art languages
- meet requirements from typical application domains
- example: supported tree and cross-tree constraints

Orthogonal Levels: independent of expressiveness

- Modularity with feature-model interfaces or slicing
- Feature versions and temporal validity with hyper and temporal feature models



## Part I

- **The Situation 110 Years Ago: Ford Model T**
- **Today: Every Second Car has a Unique Configuration**
- **Constraints Among Features are Challenging**
- **Variability Models as Central Knowledge Database**



## Part II

- **Real-World Variability Modeling**
- **One Product Line Specified with Different "Languages"**
- **Variability Modeling par Excellence**
- **Clone-and-Own of Variability Models**
- **Anomalies in Variability Models**
- **Configuration Spaces Tend to Grow Over Time**

## Part III

- **Why to Use SAT Solvers for Variability Analysis?**
- **Missing Analyses for Feature Attributes**
- **Industry Demands for Modularity and Branching**
- **Language Levels for Feature Modeling Notations**

# On Language Levels for Feature Modeling Notations

Part I

Part II

Part III