

On Language Levels for Feature Modeling Notations

<u>Thomas Thüm</u>, 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







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.

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 A car without Microsoft Office 365?!?	£ 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





Display

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

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

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.

SELECTED	

+£91.20

+£159.60





Constraints Among Features are Challenging







Variability Models as Central Knowledge Database



Technische Universität Braunschweig



Part II

The Need for Variability Analyses



Real-World Variability Modeling



- 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"







	∙ र <u>8</u> र ⇒	vm.xtsx -	Excel			6 – 0	×
File	Home Insert	Page Layout Formulas Data Review View ACROBAT Q T	ell me what you want to do			Sign in A S	hare
B512	* I ×	f _x The last feature in my example					۷
	А	В	С	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	
4	GHI	Another feature	01/04/2019		Thomas	07/03/2019	
5	JKL	The feature you cannot afford	01/07/2019		Thomas	05/01/2019	
6	MNO	A feature you don't need	01/04/2019	01/07/2019	Thomas	10/02/2019	
7	PQR	A feature that noone needs	01/04/2019	01/03/2019	Thomas	05/03/2019	
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							
515	Taballat						v
Ready	(abelle1	•	: 4		III (II)		190 %





	∙ र <u>8</u> र ⇒	vm.xlsx -	Excel			6 – 0	×
File	Home Insert	Page Layout Formulas Data Review View ACROBAT Q T	'ell me what you want to do			Sign in A S	hare
C6	* I ×	√ <i>f</i> _* 01/04/2019					۷
	А	В	С	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	
4	GHI	Another feature	01/04/2019		Thomas	07/03/2019	
5	JKL	The feature you cannot afford	01/07/2019		Thomas	05/01/2019	
6	MNO	A feature you don't need	01/04/2019	01/07/2019	Thomas	10/02/2019	
7	PQR	A feature that noone needs	01/04/2019	01/03/2019	Thomas	05/03/2019	
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							
515							
Ready	fabelle1	(+)	: •			······································	190 %





	ರಿಗಿ ⊜ಿ ಕೆಗೆ ಕ	vm.xlsx -	Excel			6 – 0	×
File	Home Insert	Page Layout Formulas Data Review View ACROBAT Q T	ell me what you want to do			Sign in A S	hare
C8	* I ×	- A V					۷
	А	В	С	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	
4	GHI	Another feature	01/04/2019		Thomas	07/03/2019	
5	JKL	The feature you cannot afford	01/07/2019		Thomas	05/01/2019	
6	MNO	A feature you don't need	01/04/2019	01/07/2019	Thomas	10/02/2019	
7	PQR	A feature that noone needs	01/04/2019	01/03/2019	Thomas	05/03/2019	
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							
515							v
Ready	fabelle1	(+)				······································	190 %





	∙ र <u>8</u> र ⇒	vm.xlsx	- Excel			6 – 6	×
File	Home Insert	Page Layout Formulas Data Review View ACROBAT Q	Tell me what you want to do			Sign in 🔉 S	hare
C7	* I ×	√ <i>f</i> _* 01/04/2019					۷
	А	В	С	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	
4	GHI	Another feature	01/04/2019		Thomas	07/03/2019	
5	JKL	The feature you cannot afford	01/07/2019		Thomas	05/01/2019	
6	MNO	A feature you don't need	01/04/2019	01/07/2019	Thomas	10/02/2019	
7	PQR	A feature that noone needs	01/04/2019	01/03/2019	Thomas	05/03/2019	
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							
515		0					
Ready	fabelle1	(±)				······································	190 %





8	5+∂-&+∓	constraints-in-excel.x	lsx - Excel			œ – ø	×
File	Home Insert F	age Layout Formulas Data Review View ACROBAT Q Tell m	e what you want to do			Sign in 🤱	Share
B2	* I × ~	∫ ABC implies DEF					۷
	Α	В	С	D	Е	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	С3	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							
-10	> Tabelle1		: •				• •
Ready						+	180 %





₿	• - ి - శి - ≐	constraints-in-excel.	dsx - Excel			œ – ø	×
File	Home Insert I	lage Layout Formulas Data Review View ACROBAT ${\mathbb Q}$ Tell n	ne what you want to do			Sign in 🔒	Share
B5	* : × ~	fe ABC and DEF implies GHI or ZAB					¥
	А	В	С	D	Е	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	С3	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							
FAC	Tabelle1	(+)	: 4				
Ready						+	180 %





Clone-and-Own of Variability Models

	ne inen	PageLeyou	t formulas Outa Rollow View ACROBAT Q	Tell me what you want	13 60						Signin J	R Star
		v #	The last feature in my example									
	A		В	C			D	E		F		
Feat	ture ID	Featu	re Name	Start Date	8	End D	ate	Edito	r La	st Mo	dified	1
ABC		A feat	ure	01/04/2	019			Thom	as	11/0	3/201	.9
DEF		A grea	at feature	01/07/2	019			Thom	as	27/0	2/201	.9
GHI		Anoth	er feature	01/04/2	019			Thom	as	07/0	3/201	9
JKL		The fe	ature you cannot afford	01/07/2	019			Thom	as	05/0	1/201	9
MN	0	A feat	ure you don't need	01/04/2	019	01/07	7/2019	Thom	as	10/0	2/201	9
PQR	ŧ	A feat	ure that noone needs	01/04/2	019	01/03	3/2019	Thom	as	05/0	3/201	9
stu		A feat	ure never built					Thom	as	20/0	1/201	9
vw)	х	A desi	cription that noone understands	01/10/2	019			Thom	as	25/0	1/201	9
ΥZ		The la	ist feature in my example	01/04/2	019			Thom	as	28/0	2/201	9
н	*) 4		199	nerts in excitate - b	1.1	_		18				
14 14	Tabelat	() I a a I a a a	tare hystopout formulas Data Roiner View 4/2/06 6. anti-auto-tare	taints in exceluter - b M — ♀ tell me una	od Lyte ne	ere 10 60		8				- Synte
H In N	Tabelat •) • <> = & Horse •	⊕ Initiation R v	erre hystograd Farmala Ode Rasian Var ADIOB A AdCorphesist B	tains in ecclute - b M — Q Tatine who	od Lyna we	ert 10 60		100				- 5910
- 14 14	Totelat	() Internet () Internet () A	regelational francesias (state for factorial (state flowing) Vanie (2006) f. f. Addit uniques (107 B Constraint	talina in acclube - b M ♀ 1strae una St	od Lyne we Gart D	c Date	D End Da	and the second s	Editor	Las	F Moc	- September
н та 1 2	Tabelat	() Nort () Nort () Nort () Nort ()	rent And American Data Anciene Vani ACIE A ARC myslen DDF ARC impolies DDF	toarto in excelutor ito N² ♀ toti neciuno St	of of art D 1/04	crito do C Date 1/2019	D End Da	ate at the second secon	E Editor	Las	F t Moc 11/03	dified
Ei 720 11 2 3	Tabelat three Constra C1 C2	() () () () () () () () () () () () () (201 April Termin Dir Annu Ver Arros 6 Accupite Str B Constraint ABC implies DEF ABC implies DFF AGC implies DFF	name in accide to © 161 records St 0 0	art [1/04	C Date 1/2019	D End Da	o ate	E Editor Thoma	Las	F t Moc 11/03 27/02	dified (/201
Ei 1% 1 2 3 4	Tabelet 1	() Internet of the second seco	Att Data Name Val Att Att Att Name Val Att Att <td>Non O</td> <td>art D 1/04 1/07</td> <td>C Date 1/2019 7/2019</td> <td>D End Da</td> <td>) ate</td> <td>E Editor Thoma Thoma</td> <td>Las</td> <td>F t Moc 11/03 27/02 07/03</td> <td>dified /201</td>	Non O	art D 1/04 1/07	C Date 1/2019 7/2019	D End Da) ate	E Editor Thoma Thoma	Las	F t Moc 11/03 27/02 07/03	dified /201
Ei 1∞ 1 2 3 4 5	Telestet Hore Constra C1 C2 C3 C4	() Votet P X alint ID	An and a set of the se	Normal in according to V V V tel we color St 0 NO 0 0 0 0 0 0 0 0 0 0 0 0 0 0	(art [1/04 1/07 1/04	C Date 4/2019 7/2019 4/2019 7/2019	D End Da) bite	E Editor Thoma Thoma Thoma	Las	F t Moc 11/03 27/02 07/03 05/01	lified /201 /201 /201
H 14 12 3 4 5 6	Constra C1 C2 C3 C4 C5	() North ()	A deruption the lange view and A deruption the ABC implies DEF ABC implies DEF or GHI ABC implies DEF or GHI ABC implies DEF or CHI or ZAB ABC implies GHI or ZAB ABC implies GHI or ZAB	None of the second seco	(art [1/04 1/07 1/04	C Date 1/2019 7/2019 7/2019 7/2019 7/2019	D End Da 01/07) ete /2019	E Editor Thoma Thoma Thoma Thoma	Las is is is is	F t Moc 11/03 27/02 07/03 05/01 10/02	lifiec 1/201 1/201 1/201
11 12 3 4 5 6 7	Constra C1 C2 C3 C4 C5 C6	() Nort () Nort () Nort () Nort ()	Ac update to the first of the second of	St O NO O O O O O O O O O O O O O O O O O	(art [1/04 1/05 1/04 1/04 1/04	v/15 65. C Date 4/2019 7/2019 4/2019 4/2019 4/2019 4/2019	D End Da 01/07 01/03	/2019 /2019	E Editor Thoma Thoma Thoma Thoma Thoma	Las is is is is	F t Moc 27/02 07/03 05/01 10/02 05/03	dified 1/201 1/201 1/201 1/201 1/201
H 1∞ 1 2 3 4 5 6 7 8	Telestet 10000 Constru- C1 C2 C3 C4 C5 C6 C7	() () () () () () () () () ()	A discussion to the acceleration of the accele	Starborn and day 10 Starborn and NO 0 NO 0 O NO 0 NO 0	(art [1/04 1/07 1/04 1/07	C Date 4/2019 7/2019 7/2019 4/2019 4/2019	D End Da 01/07, 01/03	/2019 /2019	E Editor Thoma Thoma Thoma Thoma Thoma Thoma	Las is is is is is is	F t Moc 11/03 27/02 07/03 05/01 10/02 05/03 20/01	difiec //201 //201 //201 //201 //201 //201
 № № 1 2 3 4 5 6 7 8 9 	Telestet 10000 Construct C1 C2 C3 C4 C5 C6 C7 C8	() () () () () () () () () ()	Add update 100 Add Add Add Add Add Add Add Add Add A	Steller in and data its Steller NO 0 NO 0 NO 0 NO 0 NO 0 NO 0 NO 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	(art [1/04 1/07 1/04 1/07 1/04 1/04	C Date 4/2019 7/2019 4/2019 4/2019 4/2019 4/2019 4/2019 0/2019	D End Da 01/07, 01/03,) ite /2019 /2019	E Editor Thoma Thoma Thoma Thoma Thoma Thoma Thoma	Las Is Is Is Is Is Is	F t Moc 11/03 27/02 07/03 05/01 10/02 05/03 20/01 25/01	dified //201 //201 //201 //201 //201 //201 //201
1 1 2 3 4 5 6 7 8 9 512	Tabatlat *) & Hore Constru- C1 C2 C3 C4 C5 C6 C7 C8 C511	() Next 1 N V A		Sterio o contrato da la	art [1/04 1/05 1/04 1/04 1/04 1/04 1/04	C Date 4/2019 7/2019 4/2019 4/2019 4/2019 4/2019 0/2019 4/2019	D End Da 01/07, 01/03	/2019 /2019	E Editor Thoma Thoma Thoma Thoma Thoma Thoma Thoma Thoma	Las 15 15 15 15 15 15 15 15 15	F t Moc 27/02 07/03 05/01 10/02 20/01 22/01 25/01 28/02	dified //201 //201 //201 //201 //201 //201 //201 //201
1 1 2 3 4 5 6 7 8 9 512 513	Tabatlat *) & Hore Constru- C1 C2 C3 C4 C5 C6 C7 C8 C511	() International Second	Alexa	St 00 00 00 00 00 00 00 00 00 00 00 00 00	(art [1/04 1/07 1/04 1/04 1/10 1/10	C Date 4/2019 7/2019 4/2019 4/2019 4/2019 0/2019 4/2019	D End Da 01/07 01/03	/2019 /2019	E Editor Thoma Thoma Thoma Thoma Thoma Thoma Thoma	Las 15 15 15 15 15 15 15 15 15	F t Moc 27/02 07/03 05/01 10/02 205/03 20/01 25/01 25/01	difiec /201 /201 /201 /201 /201 /201 /201 /201



THE PLAN AND A 197



Clone-and-Own of Variability Models

-	here i					
8512	A	B	с	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
4	GHI	Another feature	01/04/2019		Thomas	07/03/2019
5	JKL	The feature you cannot afford	01/07/2019		Thomas	05/01/2019
6	MNO	A feature you don't need	01/04/2019	01/07/2019	Thomas	10/02/2019
7	PQR	A feature that noone needs	01/04/2019	01/03/2019	Thomas	05/03/2019
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						
\$15						

8	9+0-\$++	control in codi	atur - tacal			m - a	×
f Re	Home losst	PapeLayout Formulas Outa Roview Yaon ACROBAT 🖓 Tell-	me what you want to do			Sign in All	her
82		fi ABC implies DEF					
1	A	В	с	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							
eac	· Tabelle1						

	IX v	f. The last feature	e in my example						
	A		В	С		D	E		F
Fea	ture ID	eature Name		Start Date	End D	ate Ed	itor	Last Mo	odified
ABC	:)	A feature		01/04/2019)	Th	omas	11/0	3/2019
DEF	:)	A great featur	e	01/07/2019)	Th	omas	27/0	2/2019
GHI		Another featu	re	01/04/2019)	Th	omas	07/0	3/2019
JKL	1	The feature yo	ou cannot afford	01/07/201)	Th	omas	05/0	1/2019
MN	0	A feature you	don't need	01/04/201	01/0	7/2019 Th	omas	10/0	2/2019
PQF	2	A feature that	noone needs	01/04/201	01/0	3/2019 Th	omas	05/0	3/2019
STU	, I	A feature neve	er built			Th	omas	20/0	1/2019
vw	x ,	A description	that noone understands	01/10/201)	Th	omas	25/0	1/2019
ΥZ	1	The last featur	e in my example	01/04/201)	Th	omas	28/0	2/2019
	Language (11)	20-							
	Taballal	۲					101 10	(1) e -	
	Tabelet	۲		1 (_	10 1	() • · ·	-1 + -
-	Tabatat *5 - ci - & - Horse	• 1 reat PageLayout #	tern Ierruhe Data Rotov Veze ACEO	trainto in anodista - bost M ♀ Tali me what you	ward 10 do			2 -	n e s m e Sprie
- 	Tabellet •) = c ² - & - Hore • 1	 I Figstagest N √ fs 4801 	terr umulas Data Roten Ven ACROB mplass.017	Tri Narns in acclute - bod M Talme what you	uard 19 60		11 0	2 -	n - Sprie
10 14 14	Tabellet	 Topologout A X √ S ARCO 	ena termulas Datas Rester Veux ACROB niçubes DEP B	E (minto in exceluter - Bool M — Q Tell me what you	uard 10 do	D			n - Syste
6 16 1	Tabelet Pore of the former of	Bystagent A S	errude Data Keten Ven ACROB nyeles Str B nt	namb in excluder. Bod R ² © Talme whet yee Start	C Date	D End Date	Edit	E La	E Sprie
1 2	Tabelet Pore Constrai C1	The figure of t	erre umuda Gda Actore Verr ACRCA nyt Act DEF Ilies DEF	namb in ancide - Rod № © tel ne what yes Start 01/0	C Date 14/2019	D End Date	Edit Tho	E La mas	F st Modifie 11/03/20
1 1 2 3	Tabelet Pore A Constrail C1 C2	Populación P	enter enter Ora Resear Vea ACCO region Br Int Billes DEF Illes DEF Illes DEF or GHI	Norma in excelute. Excel C C tot nec where you Start 01/0 01/0	C Date 14/2019	D End Date	Edit Tho	E La mas	F st Modifie 11/03/20 27/02/20
1 2 4	Tabelet Pore Constrail Constrail C1 C2 C3	ABC imp ABC imp ABC imp	aroute 0.4 Revea Van 4000 modes 507 B Int B Illes DEF Villes DEF or GHI Illes DEF or GHI IIIso DEF or GHI IIIso DEF or GHI IIIso DEF or GHI IIIso DEF or GHI III	Nerebox excelde - bod 2 € 1d excelde - bod 5 Start 01/0 01/0 01/0 01/0	C Date 14/2019 17/2019	D End Date	Edit Tho Tho	E La mas mas	F st Modifie 27/02/20 07/03/20
El 12 12 3 4 5	Takelet Hore Constrai C1 C2 C3 C4	Page Looket Page Looket Page Looket A A A A	annota data Acana Var Atitol nglasi Bir B Int Illes DEF Illes DEF or GHI Illes DEF or GHI Illes DEF or GHI DEF Implies GHI or ZAB	Start 01/0 NO 01/0 01/0 01/0	C Date 14/2019 17/2019 17/2019	D End Date	Edit Tho Tho Tho	E La mas mas mas	F st Modifie 11/03/20 27/02/20 07/03/20 05/01/20
64 (m) № 1 2 3 4 5 6	Takelet Hore Constrai C1 C2 C3 C4 C5	rest Papelovat According	evenue Data Never Ven A2705 B Ilés DEF Ilés DEF Ilés DEF or GHI Ilés FOR FOR GHI DEF Implies GHI or XAL or DEF Implies GHI or ZAB	Start 01/0 NO 01/0 01/0 01/0 01/0 01/0	C Date 14/2019 17/2019 17/2019 14/2019 14/2019	D End Date 01/07/20	Edit Tho Tho Tho 19 Tho	E La mas mas mas mas mas	F st Modifie 11/03/20 27/02/20 07/03/20 05/01/20 10/02/20
1 2 3 4 5 6 7	A Constrai C1 C2 C3 C4 C5 C6	According to the second s	and Data Sea Vie Area and Data Sea Vie Area and Data Sea Vie Area Int Dies DEF or GHI DEF Implies GHI or ZAB Uies GHI DEF (MI) DEF Implies GHI	Start 01/0 NO 01/0 01/0 01/0 01/0 01/0 01/0	C Date 94/2019 97/2019 94/2019 94/2019 94/2019 94/2019	D End Date 01/07/20 01/03/20	Edit Tho Tho Tho 19 Tho 19 Tho	E La mas mas mas mas mas mas	F st Modifie 11/03/20 27/02/20 05/01/20 10/02/20 05/03/20
 Image: Image: Im	Tassist 1000 1 1000 1000	ABC imp ABC imp ABC imp ABC imp ABC and ABC and ABC and ABC and	International Data Review View A000 method Data Review View A0000 B Int Illes DEF or GHI Illes DEF or GHI Illes To FGHI IDEF Implies GHI DEF and GHI IDEF and GHI IDEF and GHI	Start Start 01/0 NO 01/0 0 0 0 0 0 0 0 0 0	C Date 14/2019 17/2019 14/2019 14/2019 14/2019	D End Date 01/07/20 01/03/20	Edit Tho Tho Tho 19 Tho 19 Tho Tho Tho	E La mas mas mas mas mas mas mas	F st Modifie 11/03/20 27/02/20 05/01/20 10/02/20 05/03/20 20/01/20
64 1/2 2 3 4 5 6 7 8 9	* 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	ABC imp ABC imp ABC imp ABC imp ABC imp ABC imp ABC and ABC and ABC and ABC and ABC and ABC and ABC and ABC and ABC and ABC imp	International Control of the second s	Start 01/0 01/0 01/0 01/0 01/0 01/0 01/0 01/	C Date 14/2019 17/2019 14/2019 14/2019 14/2019 14/2019 14/2019	D End Date 01/07/20 01/03/20	Edit Tho Tho Tho 19 Tho 19 Tho Tho Tho Tho	E La mas mas mas mas mas mas mas mas mas	F F 11/03/20 27/02/20 07/03/20 05/01/20 05/01/20 20/01/20 25/01/20
63 1∞ 1 2 3 4 5 6 7 8 9 512	* 1 A Constrai C1 C2 C3 C4 C5 C6 C7 C8 C511	Page Looked Page Looked Page Looked ABC Impg ABC Impg ABC Impg ABC Impg ABC Impg ABC And ABC And ABC And ABC And ABC And DEF Impg STU Impg	Band Band Band Band Band Band Band Band	Start 01// 01// NO 01// 01// 01// 01// 01// 01// 01// 01//	C Date 14/2019 17/2019 14/2019 14/2019 14/2019 14/2019 14/2019	D End Date 01/07/20 01/03/20	Edit Tho Tho Tho 19 Tho 19 Tho Tho Tho Tho Tho	E La mas mas mas mas mas mas mas mas mas mas	F F st Modifie 11/03/20 05/03/20 05/03/20 05/03/20 20/01/20 20/01/20 25/01/20 28/02/20
 Image: Second se	Taestet 1000 Constrai C1 C2 C3 C4 C5 C6 C7 C8 C511 C1	Berner Bern	And Annual State S	No 0.1/1 0.1/1 0.1/1	C Date 14/2019 17/2019 14/2019 14/2019 14/2019 14/2019 14/2019	D End Date 01/07/20 01/03/20	Edit Tho Tho Tho 19 Tho 19 Tho Tho Tho Tho	e La mas mas mas mas mas mas mas mas mas	F F st Modifie 11/03/20 07/03/20 05/01/20 05/01/20 20/01/20 22/01/20 22/01/20 22/01/20 28/02/20
1 2 3 4 5 6 7 8 9 512 513 514	Taestet Tores Tores Constrail C1 C2 C3 C4 C5 C6 C7 C8 C511 C1 C7 C8 C511 C1	Image: Second	energia de la conservación de la	Start 01/0 01/0 01/0 01/0 01/0 01/0 01/0 01/	C Date 14/2019 17/2019 14/2019 14/2019 14/2019 14/2019	D End Date 01/07/20 01/03/20	Edit Tho Tho Tho 19 Tho 19 Tho Tho Tho Tho	e La mas mas mas mas mas mas mas mas mas	F st Modifie 11/03/20 27/02/20 05/01/20 10/02/20 05/01/20 20/01/20 25/01/20 28/02/20



Thomas Thüm | On Language Levels for Feature Modeling Notations | Slide 12



THE R. P. LEWIS CO., NAME

Anomalies in Variability Models







Anomalies in Variability Models







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





Missing Analyses for Feature Attributes







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