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Hochschule für angewandte Wissenschaften

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Institut für Softwaretechnik und Fahrzeuginformatik

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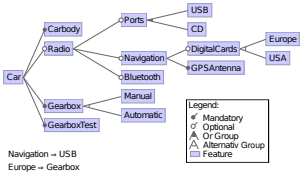
uulm

SMT-Based Variability Analyses in FeatureIDE

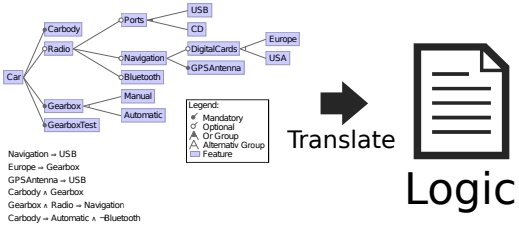
Joshua Sprey, Chico Sundermann, Sebastian Krieter, Michel Nieke, Jacopo Mauro, Thomas Thüm, Ina Schaefer, February 5, 2020

Automated Variability Analyses



Navigation → USB
Europe → Gearbox
GPSAntenna → USB
Carbody ∧ Gearbox
Gearbox ∧ Radio → Navigation
Carbody → Automatic ∧ ¬Bluetooth

Automated Variability Analyses



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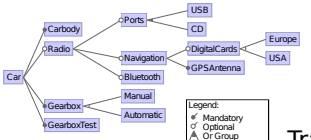

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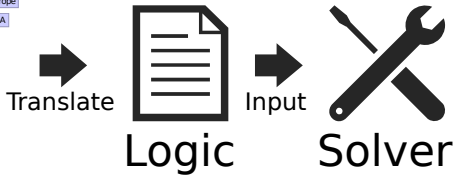

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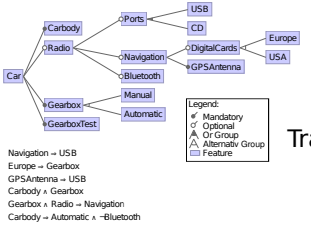

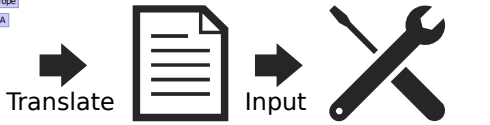

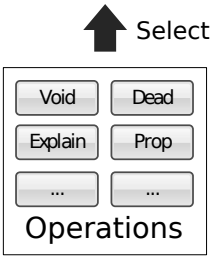

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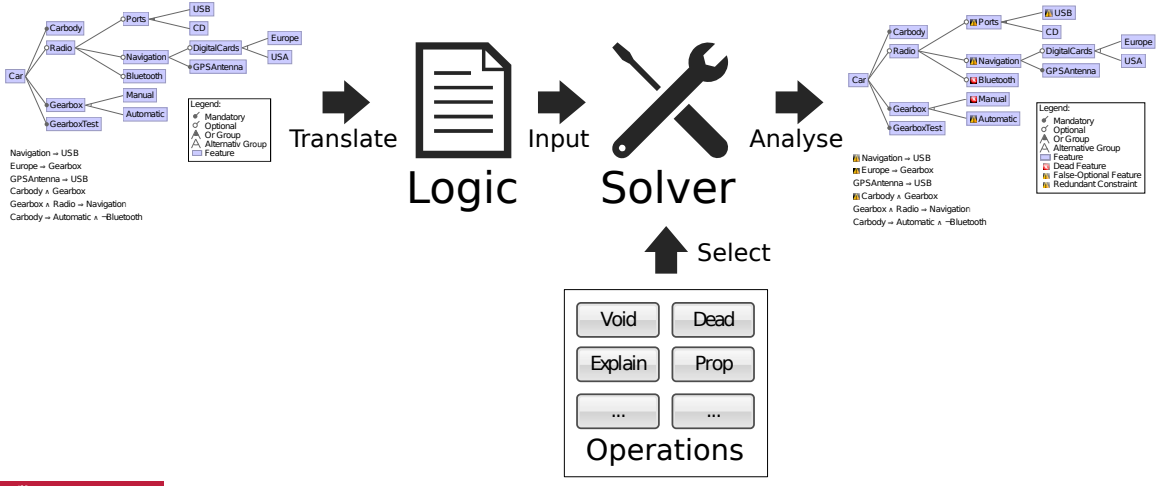

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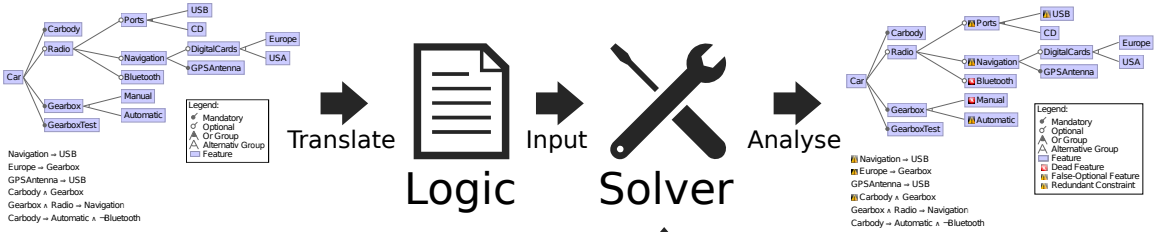
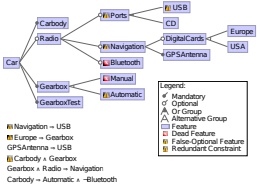


- Typically **SAT solver** are employed

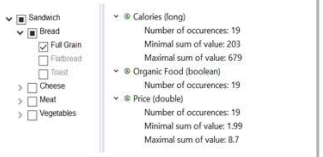
Overview

Analyses of Feature Models



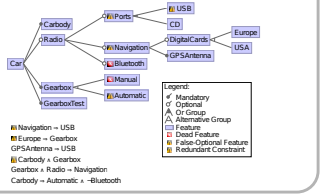
Analyses of Configurations

Attribute Range Analysis



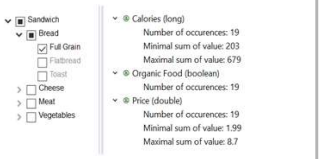
Overview

Analyses of Feature Models



Analyses of Configurations

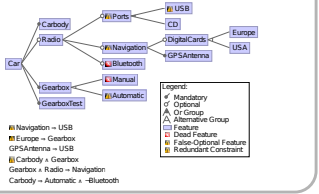
Attribute Range Analysis



- Input
  - Feature Model
- Operations (14)
  - Verification
  - Statistics

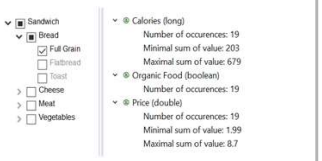
Overview

Analyses of Feature Models



Analyses of Configurations

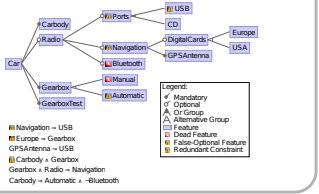
Attribute Range Analysis



- Input
  - Feature Model
  - Configuration
- Operations (5)
  - Verification
  - Support

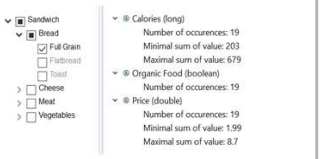
Overview

Analyses of Feature Models



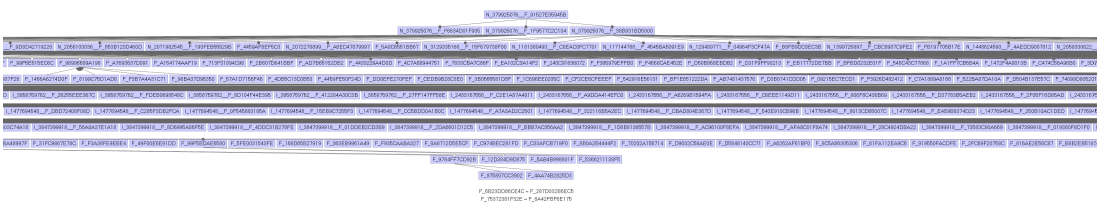
Analyses of Configurations

Attribute Range Analysis

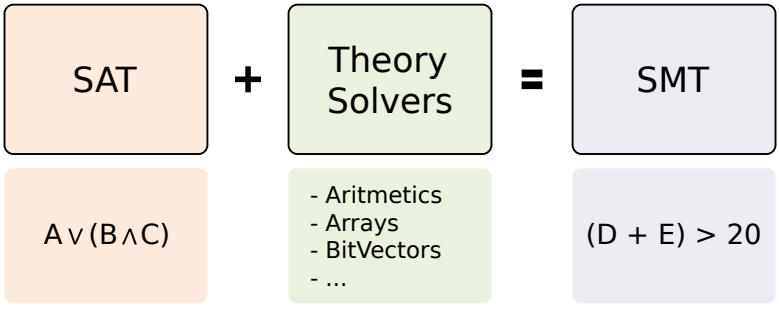


- Input
  - Extended Feature Model
  - Configuration
- Operations (1)
  - Attribute Ranges

Facing Complex Systems

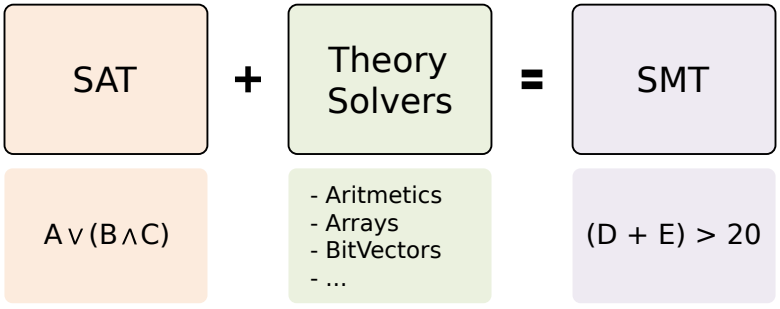


Satisfiability Module Theories (SMT)



Functionality: SAT $<$ SMT

Satisfiability Module Theories (SMT)



Functionality: SAT $<$ SMT

Efficiency: SAT **?** SMT

Contributions

1. Overview of variability analyses

Contributions

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2. Tool support to compare SAT and SMT

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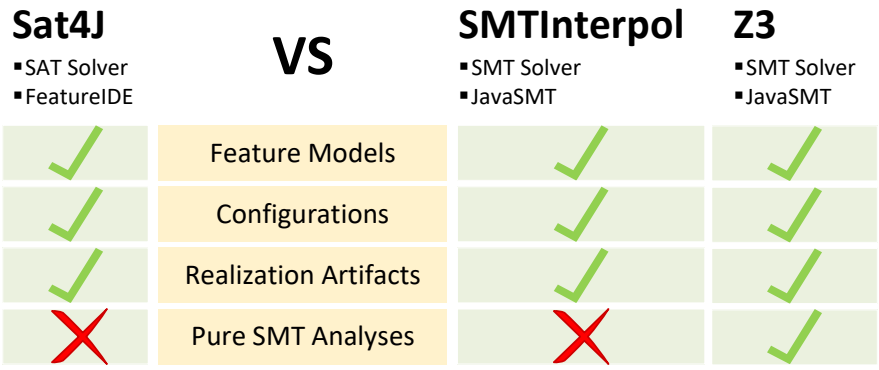
1. Overview of variability analyses
2. Tool support to compare SAT and SMT
3. Empirical evaluation of SAT vs SMT
   - RQ_1 **Are SMT solvers superior** to SAT solvers **regarding efficiency** when performing variability analyses?
   - RQ_2 **Is a combination of SAT and SMT** solvers **more efficient** for variability analyses?
   - RQ_3 **Is it efficient to calculate attribute ranges** for partial configurations **with SMT solvers**?

Tool Support With SAT and SMT Solvers



Overview

Experiment 1

Analyses of Feature Models

- 116 real-world feature models
- Features:
  1,178 – 1,408
- CTCs:
  816 – 956

Overview

Experiment 1

Analyses of Feature Models

- 116 real-world feature models
- Features: 1,178 – 1,408
- CTCs: 816 – 956

Experiment 2

Analyses of Configurations

- 1 large-scale real-world feature model
- Features: 18,616
- CTCs: 1,369

Overview

Experiment 1

Analyses of Feature Models

- 116 real-world feature models
- Features: 1,178 – 1,408
- CTCs: 816 – 956

Experiment 2

Analyses of Configurations

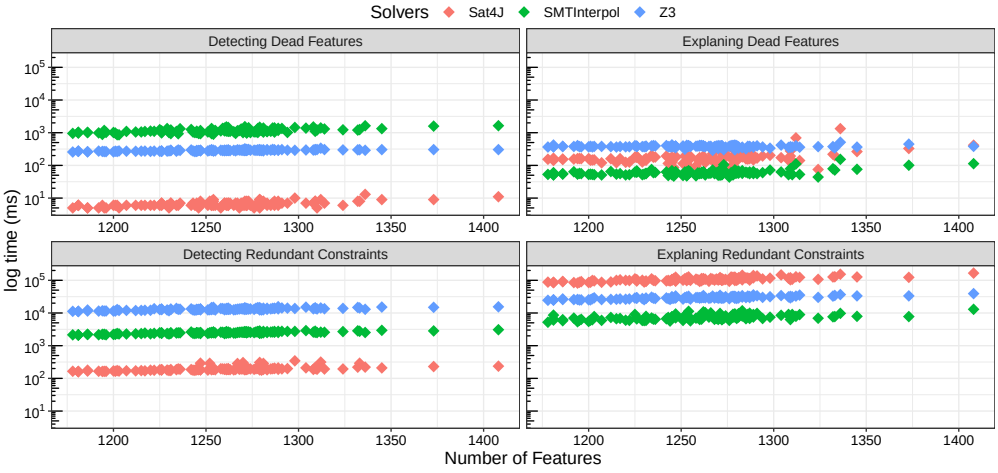
- 1 large-scale real-world feature model
- Features: 18,616
- CTCs: 1,369

Experiment 3

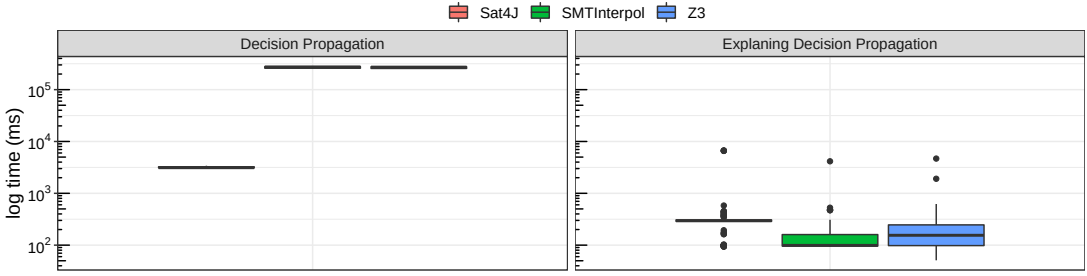
Optimization Analysis

- 3 real-world extended feature models
- Features: 19 – 377
- CTCs: 0 – 12

Results Experiment 1



Results Experiment 2



Discussion RQ_1 & RQ_2

RQ_1: Are SMT solvers superior to SAT solvers **regarding efficiency** when performing variability analyses?

- **No, but ...**
  - JavaSMT overhead
  - Missing optimizations
  - Suboptimal encoding

Discussion RQ_1 & RQ_2

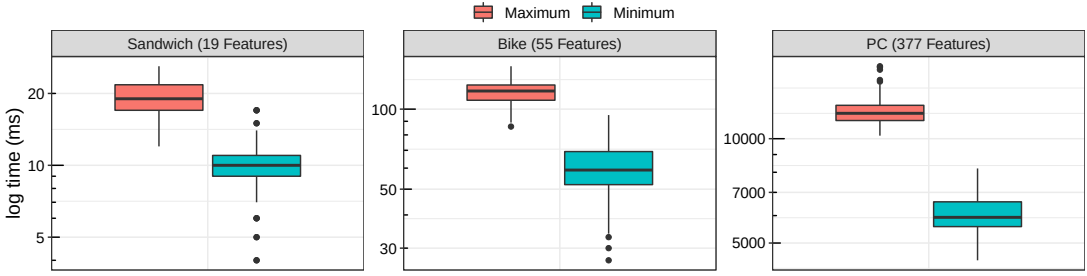
RQ_1: Are SMT solvers superior to SAT solvers **regarding efficiency** when performing variability analyses?

- **No, but ...**
  - JavaSMT overhead
  - Missing optimizations
  - Suboptimal encoding

RQ_2: Is a combination of SAT and SMT solvers **more efficient** for variability analyses?

- **Yes, for ...**
  - Explanations
    - Decision propagation
    - Redundant constraints
    - Dead features

Results Experiment 3

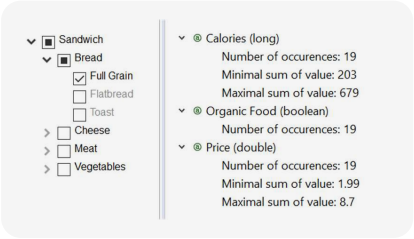


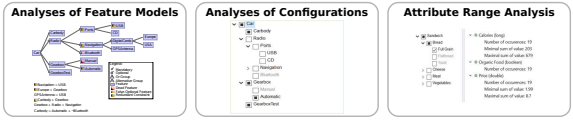
Discussion RQ_3

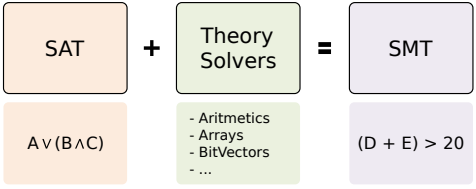
RQ_3: Is it efficient to calculate attribute ranges for partial configurations **with SMT solvers**?

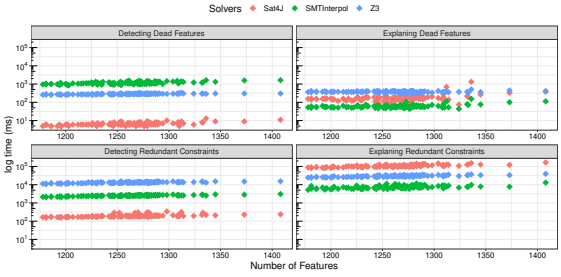
- **It depends...**
  - For small models: on-the-fly
  - For larger models: on-demand
- Possible improvements
  - JavaSMT overhead
  - Missing optimizations
- Approximation as an alternative

Conclusion


Sandwich
Bread
Full Grain
Flatbread
Toast
Cheese
Meat
Vegetables
Calories (long)
Number of occurences: 19
Minimal sum of value: 203
Maximal sum of value: 679
Organic Food (boolean)
Number of occurences: 19
Price (double)
Number of occurences: 19
Minimal sum of value: 1.99
Maximal sum of value: 8.7


Analyses of Feature Models
Analyses of Configurations
Attribute Range Analysis


SAT
+
Theory Solvers
=
SMT
A∨(B∧C)
- Aritmetics
- Arrays
- BitVectors
- ...
(D + E) > 20


Solvers
Sat4J
SMTInterpol
Z3
Detecting Dead Features
Explaning Dead Features
Detecting Redundant Constraints
Explaning Redundant Constraints
log time (ms)
Number of Features