



[Weinbergquelle, Hohenwarthe]

How Easy is SAT-Based Analysis of a Feature Model?

VaMoS 2024 — February 7–9 — Bern, Switzerland

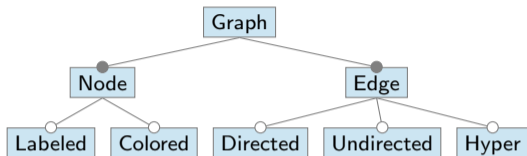
Elias Kuitert¹, Tobias Heß², Chico Sundermann², Sebastian Krieter², Thomas Thüm², Gunter Saake¹

University of Magdeburg¹, Ulm², Germany



universität
uulm

Recap: Product-Line and Feature-Model Analysis



$\neg(\text{Directed} \wedge \text{Undirected})$

$\text{Hyper} \rightarrow \text{Undirected}$

$\text{Directed} \leftrightarrow (\text{Undirected} \wedge \text{Hyper})$

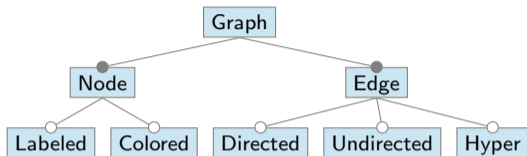
node.cpp

```
class Node {  
  #ifdef LABELED  
    std::string label;  
  #endif  
  #ifdef COLORED  
    std::string color;  
  #endif  
};
```

edge.cpp

```
class Edge {  
  #ifdef DIRECTED  
    Node from, to;  
  #elif UNDIRECTED &&  
    HYPER  
    std::set<Node> nodes;  
  #endif  
};
```

Recap: Product-Line and Feature-Model Analysis



$\neg(\text{Directed} \wedge \text{Undirected})$

$\text{Hyper} \rightarrow \text{Undirected}$

$\text{Directed} \leftrightarrow (\text{Undirected} \wedge \text{Hyper})$

Product-Line Analyses ...

[ref]

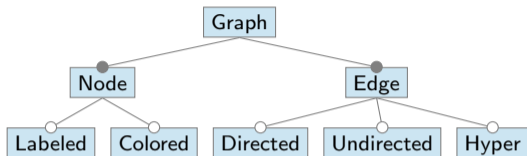
node.cpp

```
class Node {  
  #ifdef LABELED  
    std::string label;  
  #endif  
  #ifdef COLORED  
    std::string color;  
  #endif  
};
```

edge.cpp

```
class Edge {  
  #ifdef DIRECTED  
    Node from, to;  
  #elif UNDIRECTED &&  
    HYPER  
    std::set<Node> nodes;  
  #endif  
};
```

Recap: Product-Line and Feature-Model Analysis



$\neg(\text{Directed} \wedge \text{Undirected})$

$\text{Hyper} \rightarrow \text{Undirected}$

$\text{Directed} \leftrightarrow (\text{Undirected} \wedge \text{Hyper})$

Product-Line Analyses ...

[ref]

Which product(s) ...

- ... has the most **lines of code**? [ref]
- ... is the **fastest** or **smallest**? [ref, ref]
- ... have type or **logic errors**? [ref, ref]
- ... have unsafe **data flows**? [ref]

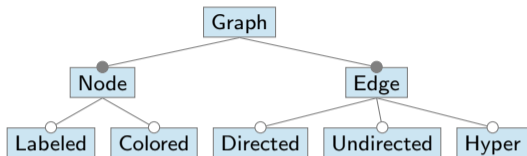
node.cpp

```
class Node {  
  #ifdef LABELED  
    std::string label;  
  #endif  
  #ifdef COLORED  
    std::string color;  
  #endif  
};
```

edge.cpp

```
class Edge {  
  #ifdef DIRECTED  
    Node from, to;  
  #elif UNDIRECTED &&  
    HYPER  
    std::set<Node> nodes;  
  #endif  
};
```

Recap: Product-Line and Feature-Model Analysis



$\neg(\text{Directed} \wedge \text{Undirected})$

$\text{Hyper} \rightarrow \text{Undirected}$

$\text{Directed} \leftrightarrow (\text{Undirected} \wedge \text{Hyper})$

node.cpp

```
class Node {  
  #ifdef LABELED  
    std::string label;  
  #endif  
  #ifdef COLORED  
    std::string color;  
  #endif  
};
```

edge.cpp

```
class Edge {  
  #ifdef DIRECTED  
    Node from, to;  
  #elif UNDIRECTED &&  
    HYPER  
    std::set<Node> nodes;  
  #endif  
};
```

Product-Line Analyses ...

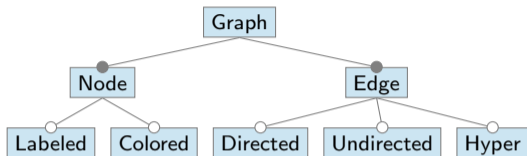
[ref]

Which product(s) ...

- ... has the most **lines of code**? [ref]
- ... is the **fastest** or **smallest**? [ref, ref]
- ... have type or **logic errors**? [ref, ref]
- ... have unsafe **data flows**? [ref]

... Often Rely on Feature-Model Analyses ...

Recap: Product-Line and Feature-Model Analysis



$\neg(\text{Directed} \wedge \text{Undirected})$

$\text{Hyper} \rightarrow \text{Undirected}$

$\text{Directed} \leftrightarrow (\text{Undirected} \wedge \text{Hyper})$

node.cpp

```
class Node {  
  #ifdef LABELED  
    std::string label;  
  #endif  
  #ifdef COLORED  
    std::string color;  
  #endif  
};
```

edge.cpp

```
class Edge {  
  #ifdef DIRECTED  
    Node from, to;  
  #elif UNDIRECTED &&  
    HYPER  
    std::set<Node> nodes;  
  #endif  
};
```

Product-Line Analyses ...

[ref]

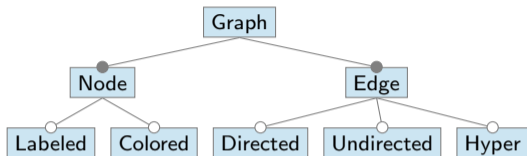
Which product(s) ...

- ... has the most **lines of code**? [ref]
- ... is the **fastest** or **smallest**? [ref, ref]
- ... have type or **logic errors**? [ref, ref]
- ... have unsafe **data flows**? [ref]

... Often Rely on Feature-Model Analyses ...

- Which features are **core/dead**? [ref]
- A sample covering all **t-wise interactions**? [ref]
- **How large** is the configuration space? [ref]
- How has the configuration space **evolved**? [ref]

Recap: Product-Line and Feature-Model Analysis



$\neg(\text{Directed} \wedge \text{Undirected})$

$\text{Hyper} \rightarrow \text{Undirected}$

$\text{Directed} \not\leftrightarrow (\text{Undirected} \wedge \text{Hyper})$

node.cpp

```
class Node {  
  #ifdef LABELED  
    std::string label;  
  #endif  
  #ifdef COLORED  
    std::string color;  
  #endif  
};
```

edge.cpp

```
class Edge {  
  #ifdef DIRECTED  
    Node from, to;  
  #elif UNDIRECTED &&  
    HYPER  
    std::set<Node> nodes;  
  #endif  
};
```

Product-Line Analyses ...

[ref]

Which product(s) ...

- ... has the most **lines of code**? [ref]
- ... is the **fastest** or **smallest**? [ref, ref]
- ... have type or **logic errors**? [ref, ref]
- ... have unsafe **data flows**? [ref]

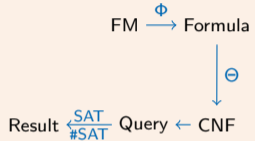
... Often Rely on Feature-Model Analyses ...

- Which features are **core/dead**? [ref]
- A sample covering all **t-wise interactions**? [ref]
- **How large** is the configuration space? [ref]
- How has the configuration space **evolved**? [ref]

... which often rely on **SAT solving** (et al.)!

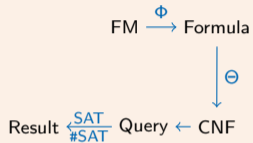
Recap: Product-Line and Feature-Model Analysis

A Typical Analysis Pipeline

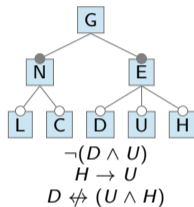


Recap: Product-Line and Feature-Model Analysis

A Typical Analysis Pipeline

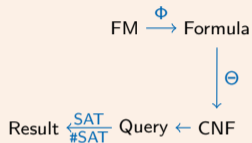


A Feature Model FM

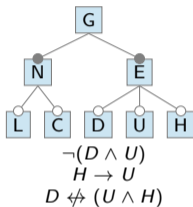


Recap: Product-Line and Feature-Model Analysis

A Typical Analysis Pipeline



A Feature Model FM



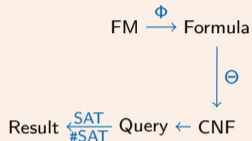
$\Phi \rightarrow$

As a Formula $\Phi(FM)$

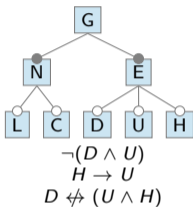
G
 $\wedge (N \leftrightarrow G) \wedge (E \leftrightarrow G)$
 $\wedge ((L \vee C) \rightarrow N)$
 $\wedge ((D \vee U \vee H) \rightarrow E)$
 $\wedge \neg(D \wedge U) \wedge (H \rightarrow U)$
 $\wedge (D \nleftrightarrow (U \wedge H))$

Recap: Product-Line and Feature-Model Analysis

A Typical Analysis Pipeline



A Feature Model FM



As a Formula $\Phi(FM)$

G
 $\wedge (N \leftrightarrow G) \wedge (E \leftrightarrow G)$
 $\wedge ((L \vee C) \rightarrow N)$
 $\wedge ((D \vee U \vee H) \rightarrow E)$
 $\wedge \neg(D \wedge U) \wedge (H \rightarrow U)$
 $\wedge (D \nleftrightarrow (U \wedge H))$

$\xrightarrow{\Phi}$

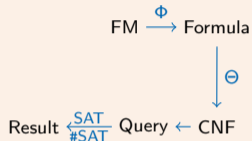
$\downarrow \Theta$

As a CNF $\Theta(\Phi(FM))$

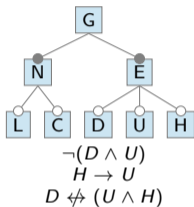
$\{\{G\}, \{\neg N, G\}, \{N, \neg G\},$
 $\{\neg E, G\}, \{E, \neg G\}, \{\neg L, N\},$
 $\{\neg C, N\}, \{\neg D, E\}, \{\neg U, E\},$
 $\{\neg H, E\}, \{\neg D, \neg U\}, \{\neg H, U\},$
 $\{\{D, U\}, \{D, H\}, \{\neg D, \neg U, \neg H\}\}$

Recap: Product-Line and Feature-Model Analysis

A Typical Analysis Pipeline



A Feature Model FM



As a Formula $\Phi(FM)$

G
 $\wedge (N \leftrightarrow G) \wedge (E \leftrightarrow G)$
 $\wedge ((L \vee C) \rightarrow N)$
 $\wedge ((D \vee U \vee H) \rightarrow E)$
 $\wedge \neg(D \wedge U) \wedge (H \rightarrow U)$
 $\wedge (D \not\leftrightarrow (U \wedge H))$

Φ

Θ

Core Features

$\{G, N, E\}$

Core Feature $F?$

$\text{SAT}(\Theta(\Phi(FM)) \wedge \neg F)$

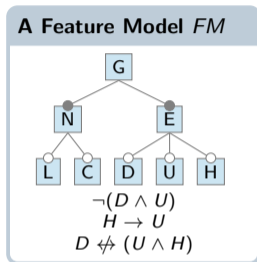
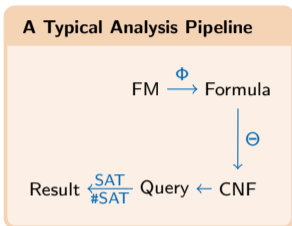
\leftarrow

\leftarrow

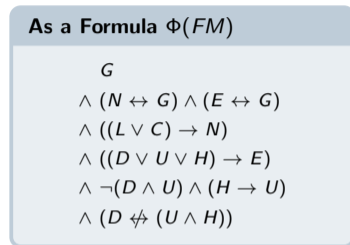
As a CNF $\Theta(\Phi(FM))$

$\{\{G\}, \{\neg N, G\}, \{N, \neg G\},$
 $\{\neg E, G\}, \{E, \neg G\}, \{\neg L, N\},$
 $\{\neg C, N\}, \{\neg D, E\}, \{\neg U, E\},$
 $\{\neg H, E\}, \{\neg D, \neg U\}, \{\neg H, U\},$
 $\{\{D, U\}, \{D, H\}, \{\neg D, \neg U, \neg H\}\}$

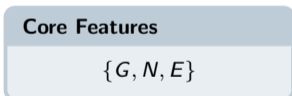
Recap: Product-Line and Feature-Model Analysis



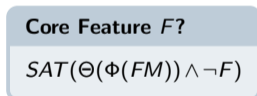
Φ



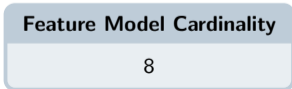
$\downarrow \Theta$



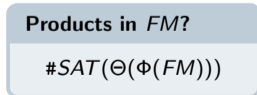
\leftarrow



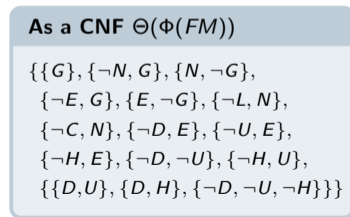
\leftarrow



\leftarrow



\leftarrow



SAT-Based Analysis of Feature Models is Easy

SAT-Based Analysis of Feature Models is Easy

SAT-based Analysis of Feature Models is Easy

Marcilio Mendonca
University of Waterloo, Canada
marcilio@csg.uwaterloo.ca

Andrzej Wasowski
IT University of Copenhagen, Denmark
wasowski@itu.dk

Krzysztof Czarnecki
University of Waterloo, Canada
kczarnec@gsd.uwaterloo.ca

SAT-Based Analysis of Feature Models is Easy

SAT-based Analysis of Feature Models is Easy

Marcilio Mendonca
University of Waterloo, Canada
marcilio@csg.uwaterloo.ca

Andrzej Wasowski
IT University of Copenhagen, Denmark
wasowski@itu.dk

Krzysztof Czarnecki
University of Waterloo, Canada
kczarnec@gsd.uwaterloo.ca

SAT-based Analysis of Large Real-world Feature Models is Easy

Jia Hui Liang
University of Waterloo,
Canada

Krzysztof Czarnecki
University of Waterloo,
Canada

Vijay Ganesh
University of Waterloo,
Canada

Venkatesh Raman
Institute of Mathematical
Sciences, India

SAT-Based Analysis of Feature Models is Easy

SAT-based Analysis of Feature Models is Easy

Marcilio Mendonca
University of Waterloo, Canada
marcilio@csg.uwaterloo.ca

Andrzej Wasowski
IT University of Copenhagen, Denmark
wasowski@itu.dk

Krzysztof Czarnecki
University of Waterloo, Canada
kczarnec@gsd.uwaterloo.ca

“easy”

as in

**“performs much better than expected
despite being NP-complete”**

(because no phase transition is observed on typical
feature models)

SAT-based Analysis of Large Real-world Feature Models is Easy

Jia Hui Liang
University of Waterloo,
Canada

Vijay Ganesh
University of Waterloo,
Canada

Krzysztof Czarnecki
University of Waterloo,
Canada

Venkatesh Raman
Institute of Mathematical
Sciences, India

SAT-Based Analysis of Feature Models is Easy

SAT-based Analysis of Feature Models is Easy

Marcilio Mendonca
University of Waterloo, Canada
marcilio@csg.uwaterloo.ca

Andrzej Wasowski
IT University of Copenhagen, Denmark
wasowski@itu.dk

Krzysztof Czarnecki
University of Waterloo, Canada
kczarnec@gsd.uwaterloo.ca

“easy”

as in

“performs much better than expected
despite being NP-complete”

(because no phase transition is observed on typical
feature models)

SAT-based Analysis of Large Real-world Feature Models is Easy

Jia Hui Liang
University of Waterloo,
Canada

Vijay Ganesh
University of Waterloo,
Canada

Krzysztof Czarnecki
University of Waterloo,
Canada

Venkatesh Raman
Institute of Mathematical
Sciences, India

Yes, But ...

- easy = **fast**?
- what about **pre-solving steps**?
- what about **repeated solver calls**?
- are **non-SAT analyses** also easy?
- are all feature models **equally** easy?

SAT-Based Analysis of Feature Models is Easy*

SAT-based Analysis of Feature Models is Easy

Marcilio Mendonca
University of Waterloo, Canada
marcilio@csg.uwaterloo.ca

Andrzej Wasowski
IT University of Copenhagen, Denmark
wasowski@itu.dk

Krzysztof Czarnecki
University of Waterloo, Canada
kczarnec@gsd.uwaterloo.ca

SAT-based Analysis of Large Real-world Feature Models is Easy

Jia Hui Liang
University of Waterloo,
Canada

Vijay Ganesh
University of Waterloo,
Canada

Krzysztof Czarnecki
University of Waterloo,
Canada

Venkatesh Raman
Institute of Mathematical
Sciences, India

“easy”

as in

“performs much better than expected
despite being NP-complete”

(because no phase transition is observed on typical
feature models)

Yes, But ...

- easy = **fast**?
 - what about **pre-solving steps**?
 - what about **repeated solver calls**?
- are **non-SAT analyses** also easy?
- are all feature models **equally** easy?

*on most instances, for most purposes

How Bad is It?

How Bad is it?

Linux kernel

- number of configurations unknown past 2007
- family-based type checking infeasible
- as uniform random sampling, slicing, diffing, ...
- even core dead features are challenging

same of FreeBSD, Bluetooth, Automotive02, ...

Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

From Class-Based Meta-Analysis ...

... to Instance-Based Meta-Analysis

Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

From Class-Based Meta-Analysis ... [ref, ref]

- “Is SAT-based analysis of feature models easy?”
- “Is SAT-based analysis of large real-world feature models easy?”

... to Instance-Based Meta-Analysis

Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

From Class-Based Meta-Analysis ...

[ref, ref]

- “Is SAT-based analysis of feature models easy?”
- “Is SAT-based analysis of large real-world feature models easy?”

... to Instance-Based Meta-Analysis

- “How much time does analysis X need on feature model Y when using solver Z?”
- “Which algorithm is most memory-efficient for computing X on Y?”

Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

From Class-Based Meta-Analysis ...

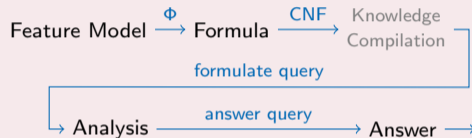
[ref, ref]

- “Is SAT-based analysis of feature models easy?”
- “Is SAT-based analysis of large real-world feature models easy?”

... to Instance-Based Meta-Analysis

- “How much time does analysis X need on feature model Y when using solver Z?”
- “Which algorithm is most memory-efficient for computing X on Y?”

Influence Factors for Feature-Model Analysis



Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

From Class-Based Meta-Analysis ...

[ref, ref]

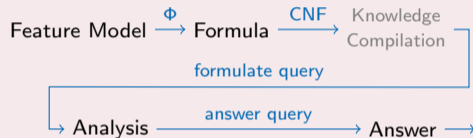
- “Is SAT-based analysis of feature models easy?”
- “Is SAT-based analysis of large real-world feature models easy?”

... to Instance-Based Meta-Analysis

- “How much time does analysis X need on feature model Y when using solver Z?”
- “Which algorithm is most memory-efficient for computing X on Y?”

Influence Factors for Feature-Model Analysis

origin, domain
size
expressiveness



Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

From Class-Based Meta-Analysis ...

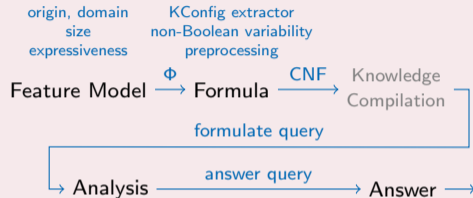
[ref, ref]

- “Is SAT-based analysis of feature models easy?”
- “Is SAT-based analysis of large real-world feature models easy?”

... to Instance-Based Meta-Analysis

- “How much time does analysis X need on feature model Y when using solver Z?”
- “Which algorithm is most memory-efficient for computing X on Y?”

Influence Factors for Feature-Model Analysis



Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

From Class-Based Meta-Analysis ...

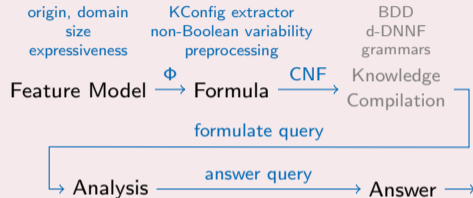
[ref, ref]

- “Is SAT-based analysis of feature models easy?”
- “Is SAT-based analysis of large real-world feature models easy?”

... to Instance-Based Meta-Analysis

- “How much time does analysis X need on feature model Y when using solver Z?”
- “Which algorithm is most memory-efficient for computing X on Y?”

Influence Factors for Feature-Model Analysis



Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

From Class-Based Meta-Analysis ...

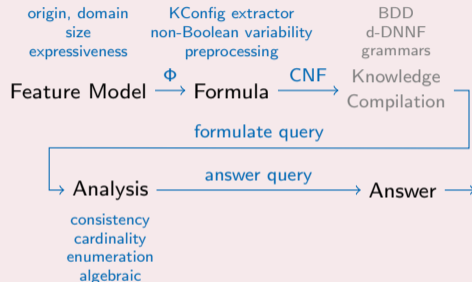
[ref, ref]

- “Is SAT-based analysis of feature models easy?”
- “Is SAT-based analysis of large real-world feature models easy?”

... to Instance-Based Meta-Analysis

- “How much time does analysis X need on feature model Y when using solver Z?”
- “Which algorithm is most memory-efficient for computing X on Y?”

Influence Factors for Feature-Model Analysis



Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

From Class-Based Meta-Analysis ...

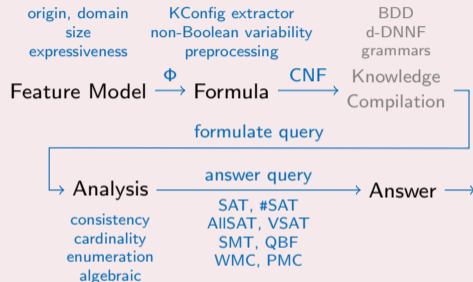
[ref, ref]

- “Is SAT-based analysis of feature models easy?”
- “Is SAT-based analysis of large real-world feature models easy?”

... to Instance-Based Meta-Analysis

- “How much time does analysis X need on feature model Y when using solver Z?”
- “Which algorithm is most memory-efficient for computing X on Y?”

Influence Factors for Feature-Model Analysis



Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

From Class-Based Meta-Analysis ...

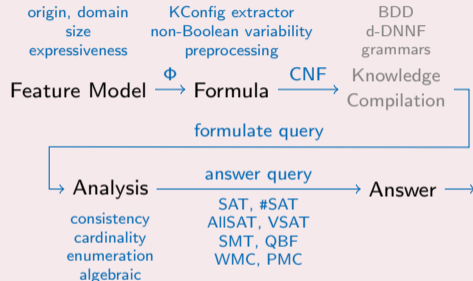
[ref, ref]

- “Is SAT-based analysis of feature models easy?”
- “Is SAT-based analysis of large real-world feature models easy?”

... to Instance-Based Meta-Analysis

- “How much time does analysis X need on feature model Y when using solver Z?”
- “Which algorithm is most memory-efficient for computing X on Y?”

Influence Factors for Feature-Model Analysis



- + **parametrization**: extractor, compiler, analysis, solver
- + **prior information**: incremental analysis, interfaces
- + **execution environment**: CPU, RAM, deep variability

Asking Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and answering questions **about** feature-model analyses

⇒ ask for **(non-)functional requirements**
(e.g., correctness, runtime, memory, energy)

From Class-Based Meta-Analysis ...

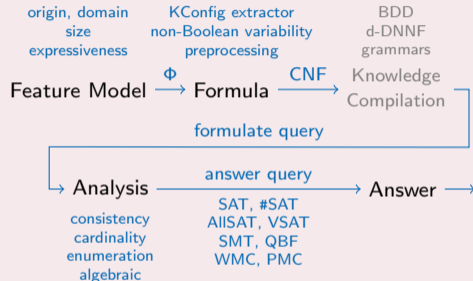
[ref, ref]

- “Is SAT-based analysis of feature models easy?”
- “Is SAT-based analysis of large real-world feature models easy?”

... to Instance-Based Meta-Analysis

- “How much time does analysis X need on feature model Y when using solver Z?”
- “Which algorithm is most memory-efficient for computing X on Y?”

Influence Factors for Feature-Model Analysis



- + **parametrization**: extractor, compiler, analysis, solver
- + **prior information**: incremental analysis, interfaces
- + **execution environment**: CPU, RAM, deep variability

for practical analysis tasks, there are many **analysis plans**

Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of asking and **answering** questions **about** feature-model analyses

Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of asking and **answering** questions **about** feature-model analyses

⇒ define **criteria** and an **algorithm** to answer the question (either exactly or an estimate)

Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of asking and **answering** questions **about** feature-model analyses

⇒ define **criteria** and an **algorithm** to answer the question (either exactly or an estimate)

Surrogate Metrics for Avoiding the Computation

Choosing Criteria & an Algorithm



Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and **answering** questions **about** feature-model analyses

⇒ define **criteria** and an **algorithm** to answer the question (either exactly or an estimate)

- syntactic metrics only give **rough estimates**
- semantic metrics probably better, but **NP-hard**
⇒ try approximating

Surrogate Metrics for Avoiding the Computation

- **syntactic** (e.g., number of features, variables, constraints, clauses, literals; constraint size, density)
- **semantic** (e.g., phase transition, community structure, self-similarity)

Choosing Criteria & an Algorithm

Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and **answering** questions **about** feature-model analyses

⇒ define **criteria** and an **algorithm** to answer the question (either exactly or an estimate)

- syntactic metrics only give **rough estimates**
- semantic metrics probably better, but **NP-hard**
⇒ try approximating
- ML is sensitive to **small changes** in the input

Surrogate Metrics for Avoiding the Computation

- **syntactic** (e.g., number of features, variables, constraints, clauses, literals; constraint size, density)
- **semantic** (e.g., phase transition, community structure, self-similarity)

Choosing Criteria & an Algorithm

- **binary** (e.g., “yes/no” for phase transition)
- **linear** (e.g., number of features \sim analysis time)
- **machine learning** techniques

Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and **answering** questions **about** feature-model analyses

⇒ define **criteria** and an **algorithm** to answer the question (either exactly or an estimate)

Surrogate Metrics for Avoiding the Computation

- **syntactic** (e.g., number of features, variables, constraints, clauses, literals; constraint size, density)
- **semantic** (e.g., phase transition, community structure, self-similarity)

Choosing Criteria & an Algorithm

- **binary** (e.g., “yes/no” for phase transition)
- **linear** (e.g., number of features \sim analysis time)
- **machine learning** techniques

- syntactic metrics only give **rough estimates**
- semantic metrics probably better, but **NP-hard**
⇒ try approximating
- ML is sensitive to **small changes** in the input

Discussion & Outlook

Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and **answering** questions **about** feature-model analyses

⇒ define **criteria** and an **algorithm** to answer the question (either exactly or an estimate)

Surrogate Metrics for Avoiding the Computation

- **syntactic** (e.g., number of features, variables, constraints, clauses, literals; constraint size, density)
- **semantic** (e.g., phase transition, community structure, self-similarity)

Choosing Criteria & an Algorithm

- **binary** (e.g., “yes/no” for phase transition)
- **linear** (e.g., number of features \sim analysis time)
- **machine learning** techniques

- syntactic metrics only give **rough estimates**
- semantic metrics probably better, but **NP-hard**
⇒ try approximating
- ML is sensitive to **small changes** in the input

Discussion & Outlook

- what meta-analysis questions are **worth asking**?

Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and **answering** questions **about** feature-model analyses

⇒ define **criteria** and an **algorithm** to answer the question (either exactly or an estimate)

Surrogate Metrics for Avoiding the Computation

- **syntactic** (e.g., number of features, variables, constraints, clauses, literals; constraint size, density)
- **semantic** (e.g., phase transition, community structure, self-similarity)

Choosing Criteria & an Algorithm

- **binary** (e.g., “yes/no” for phase transition)
- **linear** (e.g., number of features \sim analysis time)
- **machine learning** techniques

- syntactic metrics only give **rough estimates**
- semantic metrics probably better, but **NP-hard**
⇒ try approximating
- ML is sensitive to **small changes** in the input

Discussion & Outlook

- what meta-analysis questions are **worth asking**?
- which factors are relevant, how do they **interact**?

Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and **answering** questions **about** feature-model analyses

⇒ define **criteria** and an **algorithm** to answer the question (either exactly or an estimate)

Surrogate Metrics for Avoiding the Computation

- **syntactic** (e.g., number of features, variables, constraints, clauses, literals; constraint size, density)
- **semantic** (e.g., phase transition, community structure, self-similarity)

Choosing Criteria & an Algorithm

- **binary** (e.g., “yes/no” for phase transition)
- **linear** (e.g., number of features \sim analysis time)
- **machine learning** techniques

- syntactic metrics only give **rough estimates**
- semantic metrics probably better, but **NP-hard** ⇒ try approximating
- ML is sensitive to **small changes** in the input

Discussion & Outlook

- what meta-analysis questions are **worth asking**?
- which factors are relevant, how do they **interact**?
- is feature-model complexity **intrinsic**?

Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and **answering** questions **about** feature-model analyses

⇒ define **criteria** and an **algorithm** to answer the question (either exactly or an estimate)

Surrogate Metrics for Avoiding the Computation

- **syntactic** (e.g., number of features, variables, constraints, clauses, literals; constraint size, density)
- **semantic** (e.g., phase transition, community structure, self-similarity)

Choosing Criteria & an Algorithm

- **binary** (e.g., “yes/no” for phase transition)
- **linear** (e.g., number of features \sim analysis time)
- **machine learning** techniques

- syntactic metrics only give **rough estimates**
- semantic metrics probably better, but **NP-hard** ⇒ try approximating
- ML is sensitive to **small changes** in the input

Discussion & Outlook

- what meta-analysis questions are **worth asking**?
- which factors are relevant, how do they **interact**?
- is feature-model complexity **intrinsic**?
- when do advanced techniques (knowledge computation, incremental analysis, ...) **pay off**?

Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and **answering** questions **about** feature-model analyses

⇒ define **criteria** and an **algorithm** to answer the question (either exactly or an estimate)

Surrogate Metrics for Avoiding the Computation

- **syntactic** (e.g., number of features, variables, constraints, clauses, literals; constraint size, density)
- **semantic** (e.g., phase transition, community structure, self-similarity)

Choosing Criteria & an Algorithm

- **binary** (e.g., “yes/no” for phase transition)
- **linear** (e.g., number of features \sim analysis time)
- **machine learning** techniques

- syntactic metrics only give **rough estimates**
- semantic metrics probably better, but **NP-hard** ⇒ try approximating
- ML is sensitive to **small changes** in the input

Discussion & Outlook

- what meta-analysis questions are **worth asking**?
- which factors are relevant, how do they **interact**?
- is feature-model complexity **intrinsic**?
- when do advanced techniques (knowledge computation, incremental analysis, ...) **pay off**?
- long-term goal: a **meta-analyzer** that finds the best analysis plan for a given analysis task (cf. portfolio solving, relational query optimization)

Answering Meta-Analysis Questions

Feature-Model Meta-Analysis

the practice of **asking** and **answering** questions **about** feature-model analyses

⇒ define **criteria** and an **algorithm** to answer the question (either exactly or an estimate)

Surrogate Metrics for Avoiding the Computation

- **syntactic** (e.g., number of features, variables, constraints, clauses, literals; constraint size, density)
- **semantic** (e.g., phase transition, community structure, self-similarity)

Choosing Criteria & an Algorithm

- **binary** (e.g., “yes/no” for phase transition)
- **linear** (e.g., number of features \sim analysis time)
- **machine learning** techniques

- syntactic metrics only give **rough estimates**
- semantic metrics probably better, but **NP-hard** ⇒ try approximating
- ML is sensitive to **small changes** in the input

Discussion & Outlook

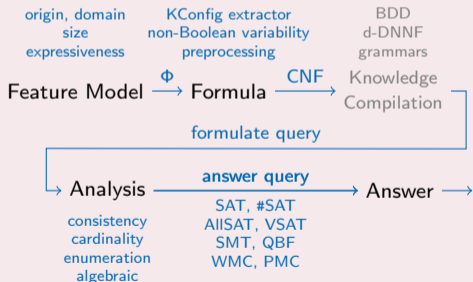
- what meta-analysis questions are **worth asking**?
- which factors are relevant, how do they **interact**?
- is feature-model complexity **intrinsic**?
- when do advanced techniques (knowledge computation, incremental analysis, ...) **pay off**?
- long-term goal: a **meta-analyzer** that finds the best analysis plan for a given analysis task (cf. portfolio solving, relational query optimization)
- tool support: FeatJAR (FeatureIDE 4.0), torte, clausy, KeYPI, PCLocator, Course on SPLs, ...

Conclusion

Feature-Model Meta-Analysis

the practice of **asking** and **answering** questions **about** feature-model analyses

Influence Factors for Feature-Model Analysis




Your opinion?


Does feature-model complexity matter for your work?

Are you doing meta-analysis?

How would you answer a meta-analysis question?



 /SoftVarE-Group/Papers

 /SoftVarE-Group/Slides