



FAKULTÄT FÜR
INFORMATIK

Representing Variability in Product Lines: A Survey of Modeling and Specification Techniques

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Background

- ▶ SPL used for safety-critical and mission-critical systems
- ▶ High degree of reliability required
- ▶ Adaption of verification techniques: growing research area
- ▶ Requires modeling and specification techniques
- ▶ **Model:** formal description of behavior
- ▶ **Specification:** formal description of properties

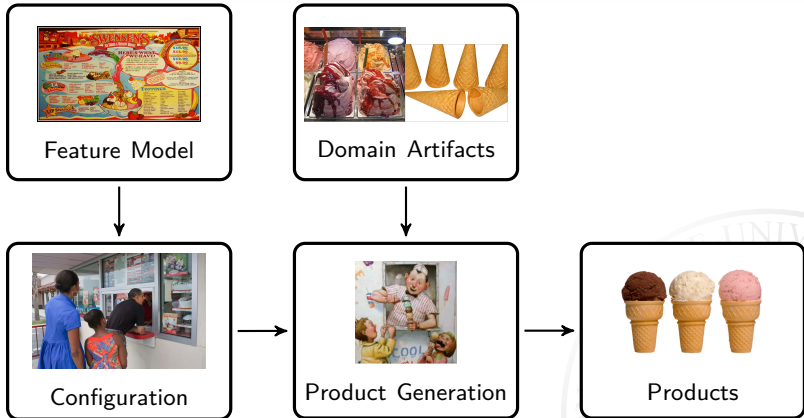


Problem

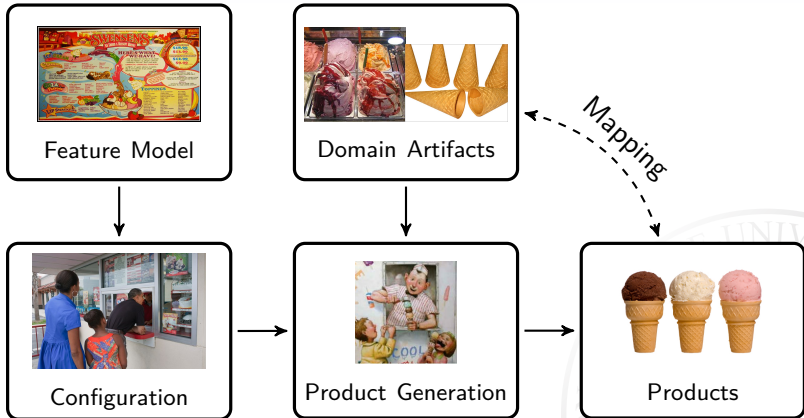
- ▶ Modeling and specification techniques proposed in diverse lines of research
- ▶ Hard to compare, hard to keep track
- ▶ Representation of variability?



Feature-Oriented Software Development



Feature-Oriented Software Development



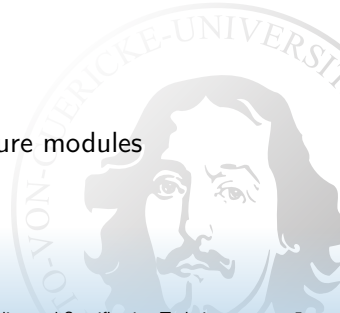
Representation of Variability: Implementation

Annotation-Based Techniques:

- ▶ Single code base
- ▶ Annotated with mapping to features
- ▶ Product generation: remove code of undesired features

Composition-Based Techniques:

- ▶ Features encapsulated into modules
- ▶ Product generation: composition of feature modules



Example: Annotation-Based (Preprocessor)

```
class Transaction { {Base, Locking}  
  void run() {  
    //if[Locking]  
    lock();  
    //end[Locking]  
    while(!operations.isEmpty) operations.pop().operate();  
    //if[Locking]  
    unlock();  
    //end[Locking]  
  }  
}
```

Example: Composition-Based (FOP)

```
class Transaction { {Base}  
  void run() {  
    while(!operations.isEmpty) operations.pop().operate();  
  } }  
•
```

```
class Transaction { {Locking}  
  void run() {  
    lock();  
    original();  
    unlock(); } }  
•
```


Example: Composition-Based (FOP)

```
class Transaction {                                     {Base}
  void run() {
    while(!operations.isEmpty) operations.pop().operate();
  } }
```

•

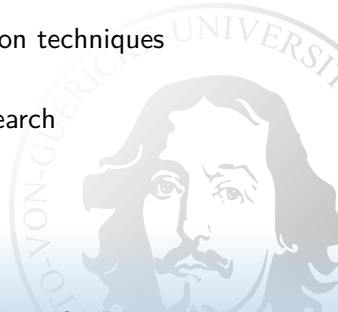
```
class Transaction {                                     {Locking}
  void run() {
    lock();
    original();
    unlock(); } }
```

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```
class Transaction {                                     {Base, Locking}
  void run() {
    lock();
    while(!operations.isEmpty) operations.pop().operate();
    unlock(); } }
```

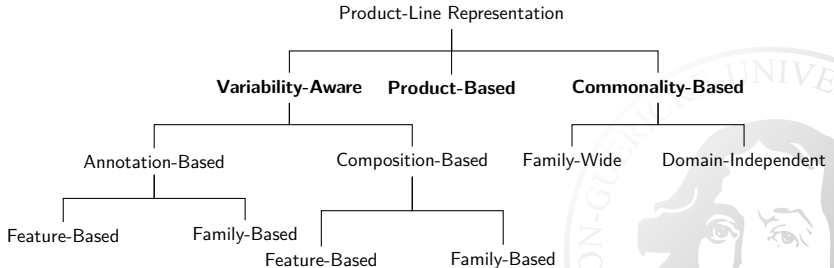
Contributions

- ▶ General taxonomy of product-line representations
→ implementation, specification, models, documentation, ...
- ▶ Survey modeling and specification techniques for software product lines
- ▶ Classification of modeling and specification techniques according to taxonomy
- ▶ Identify possible directions for future research

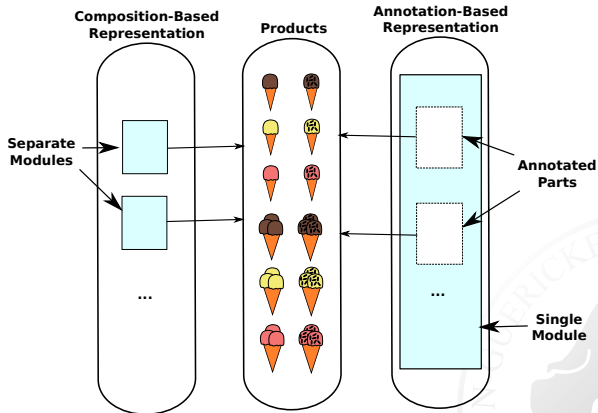


Taxonomy of Product-Line Representations

- ▶ Product-Line Representation: Set of artifacts representing characteristics such as behavior or properties of a product line
- ▶ Mapping between domain artifacts and products

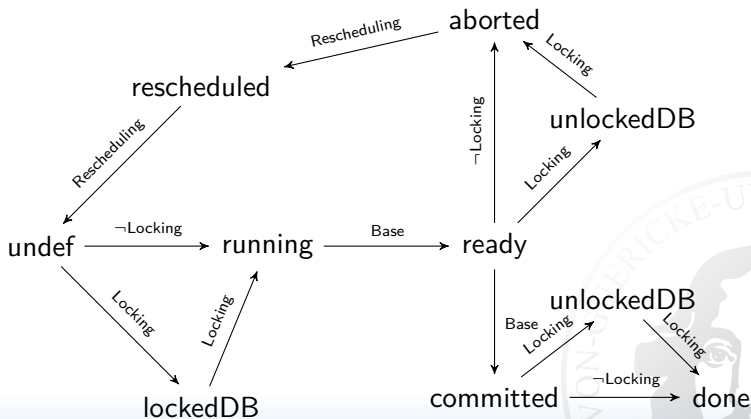


Variability-Aware Representation



Annotation-Based: Featured Transition Systems

- Mapping: Transitions annotated with feature expressions



Composition-Based: Design by Contract for FOP

```
class Transaction { {Base}  
  Queue operations;  
  /*@ ensures operations.isEmpty(); @*/  
  void run () {...}}
```

•

```
class Transaction { {Locking}  
  /*@ ensures Database.isLocked == false; @*/  
  void run () {...}}
```

Composition-Based: Design by Contract for FOP

```
class Transaction { {Base}  
  Queue operations;  
  /*@ ensures operations.isEmpty(); @*/  
  void run() {...}}
```

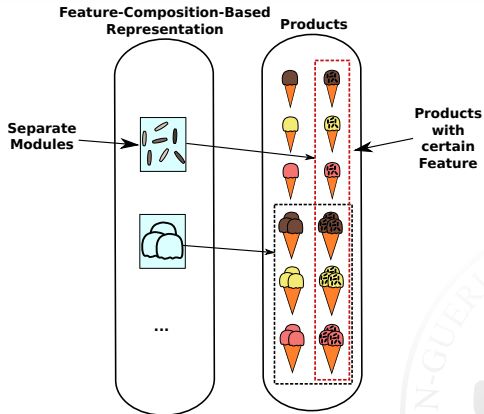
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```
class Transaction { {Locking}  
  /*@ ensures Database.isLocked == false; @*/  
  void run() {...}}
```

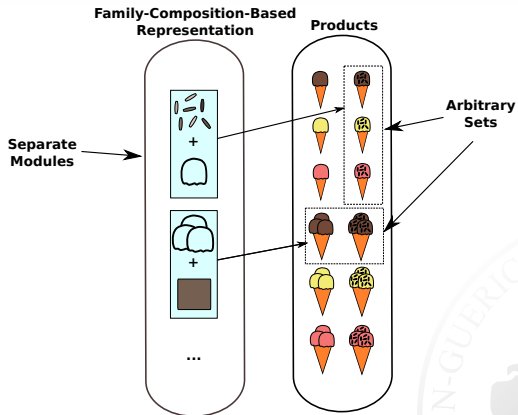
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```
class Transaction { {Base, Locking}  
  /*@ ensures operations.isEmpty()  
    && Database.isLocked == false; @*/  
  void run() { ...}}
```

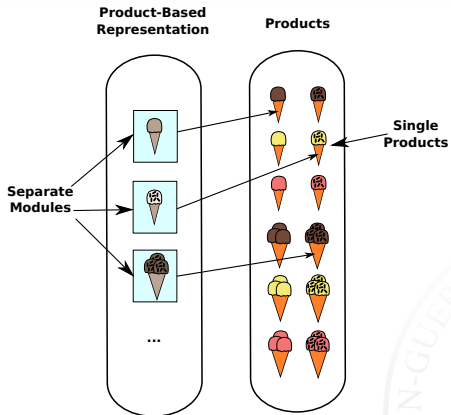
Feature-Based Representation



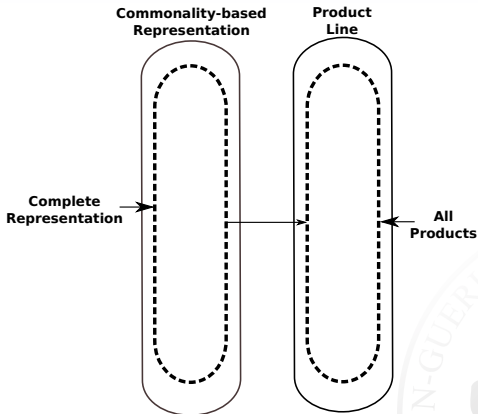
Family-Based Representation



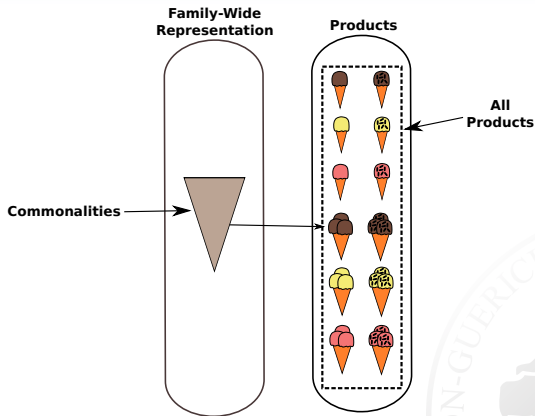
Product-Based Representation



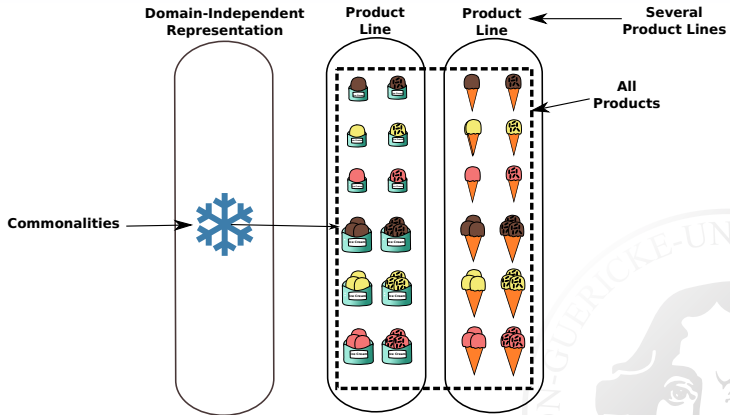
Commonality-Based Representation



Family-Wide Representation



Domain-Independent Representation



Taxonomy Overview

	#Modules	Mapping Source	Mapping Target
Product-based	-	module	single product
Commonality-based	-	representation	-
Family-wide	-	representation	all products of single product line
Domain-Independent	-	representation	all products of several product lines
Variability-aware	-	-	set of products, (not single, not same)
Composition-based	multiple	module	-
Annotation-based	single	parts of modules	-
Feature-based	-	-	all products with certain feature
Family-based	-	-	arbitrary sets of products

Annotation-Based Modeling Techniques

Formalism/Language	Feature-Based	Family-Based
Formalisms		
SHVM	✓	
FTS	✓	
Feature Petri Nets		✓
FTS		✓
A-FTS		✓
FTA		✓
GEMTS		✓
MTS		✓
Modal I/O-automata		✓
Languages		
FLan		✓
fSMV		✓
Rebeca		✓
SDVA		✓
fPromela		✓
PL-CCS		✓

Composition-Based Modeling Techniques

Formalism/Language	Feature-Based	Family-Based
Transition-Based Formalisms		
Variable IO-Automata	✓	
Transition Systems/TS+	✓	
Transition Systems	✓	
Modular Transition Systems	✓	
Languages		
Alloy	✓	
ASM	✓	
Event-B	✓	
State Charts	✓	
Promela	✓	
FSMv	✓	
Larissa	✓	
FeatureAlloy	✓	
Modal Sequence Diagrams	✓	

Specification Techniques

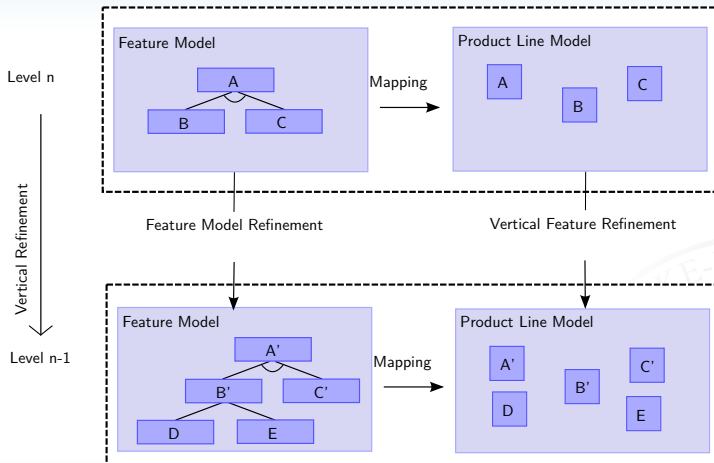
Formalism/Language	Feature-B.	Family-B.	Comp.-B.	Annot.-B.	Domain-I.	Family-W.
Variable CTL	✓			✓		
fCTL		✓		✓		
fLTL		✓		✓		
AdaCTL		✓		✓		
VMC (CTL-Based)		✓		✓		
vaCTL/MHML		✓		✓		
Service Diagrams	✓		✓			
LTL	✓		✓			
FeatureAlloy	✓		✓			
Tests	✓		✓			
Contracts (AOP)	✓		✓			
Contracts (FOP)	✓		✓			
Contracts (DOP)		✓	✓			
LTL					✓	
JPF (verification tool)					✓	
LTSA (verification tool)					✓	
CTL						✓
LTL						✓
TCTL						✓
ACTL						✓
Tests						✓

Directions for Future Research

- ▶ **Gap between problem space and solution space → model-based refinement**
- ▶ Usability of representation types / empirical evaluation
- ▶ Role of different representation types in development process
- ▶ Feature-modular representations
- ▶ Specification inference for product lines
- ▶ Generic variability-encoding
- ▶ Variability in test cases

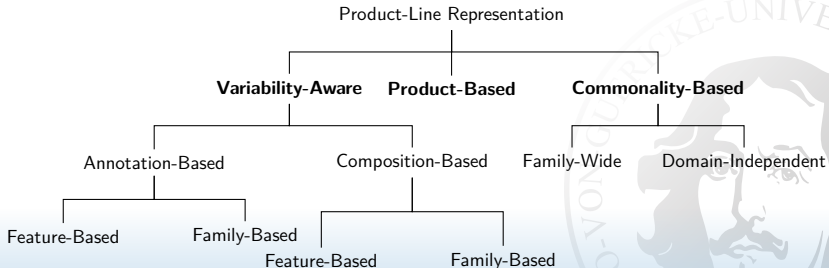


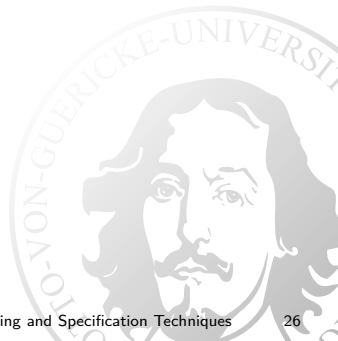
Model-Based Refinement for Product Lines



Summary

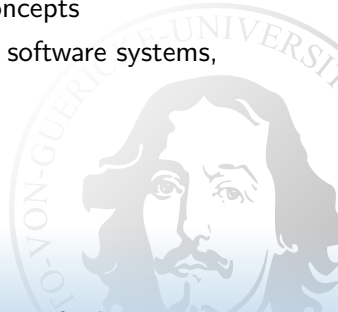
- ▶ Representation of variability required for all kind of artifacts
- ▶ Taxonomy of product-line representations
 - Helps to understand differences and commonalities
- ▶ Classification of modeling and specification techniques for product lines
 - Overview of state-of-the-art, identification of potential research directions



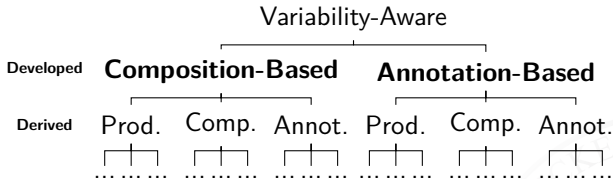


Research Scope

- ▶ Formal specification,
not: informal or semi-formal specification.
- ▶ Specification as a means to specify software systems,
not: pure formalizations of theoretical concepts
- ▶ Specification of behavior or properties of software systems,
not: pure variability modeling



Modeling Techniques



Specification Techniques

