Karlsruhe Institute of Technology

Commonalities for Preserving Consistency of Multiple Models

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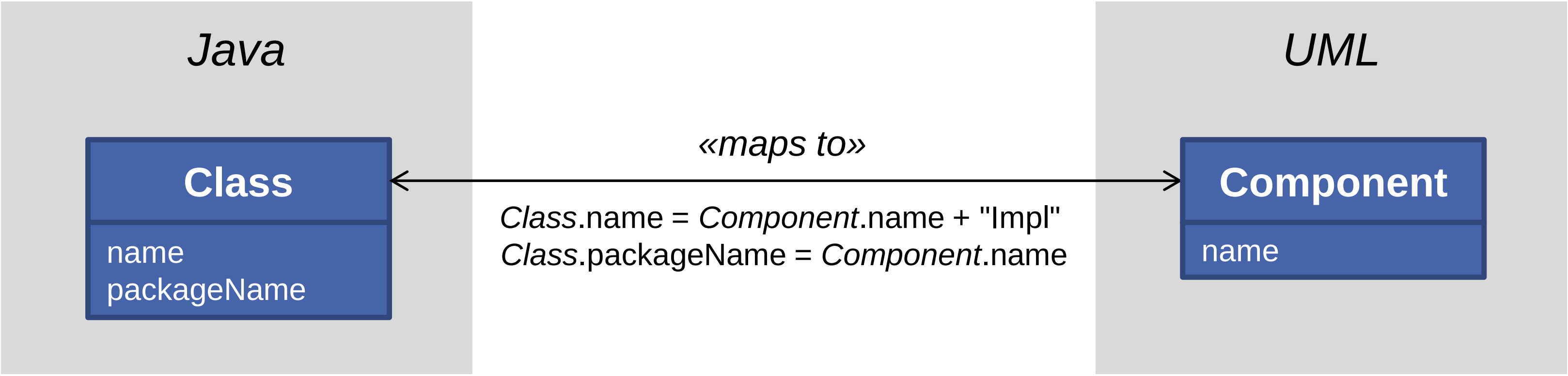
SOFTWARE DESIGN AND QUALITY GROUP
INSTITUTE FOR PROGRAM STRUCTURES AND DATA ORGANIZATION, KIT DEPARTMENT OF INFORMATICS

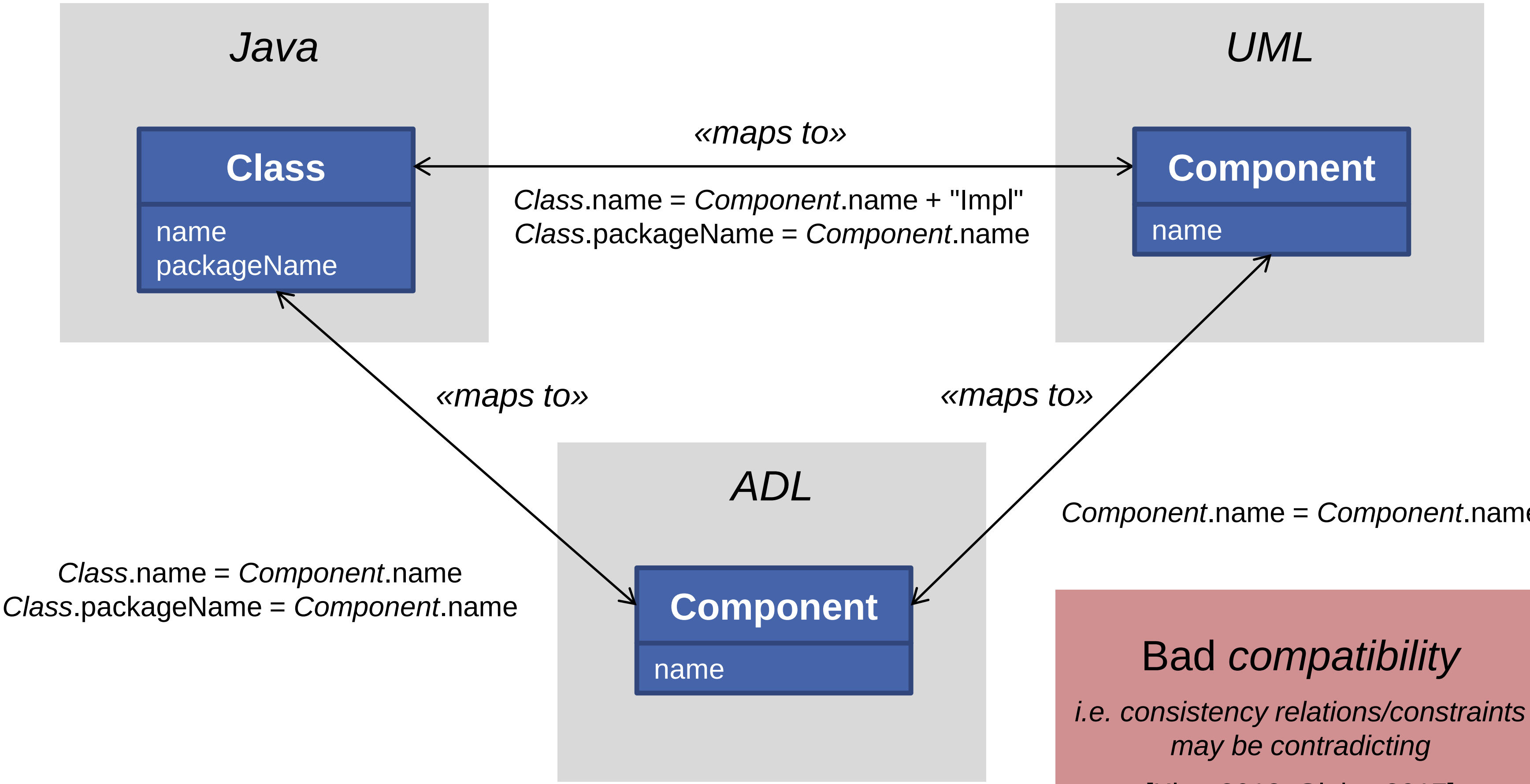
A Simple Consistency Scenario



A consistency-preserving transformation:

```
relation Class2ADLComponent {
   componentName : String;
   domain java class : Class {
     name = componentName + "Impl"
     packageName = componentName
   }
   domain uml component : Component {
      name = componentName
   }
}
```

Multi-Model Consistency: Dense Graphs



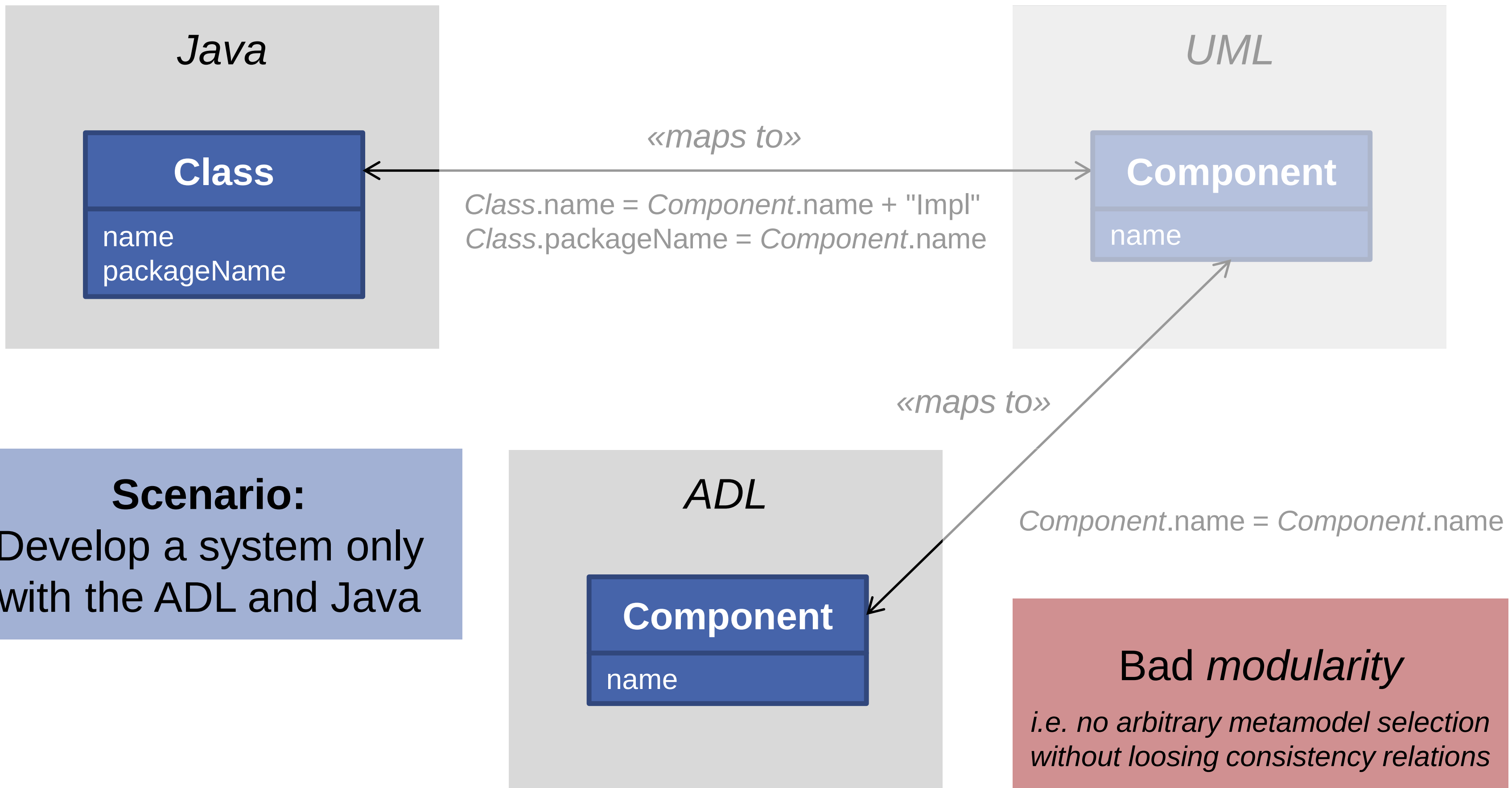
Bad *compatibility*

i.e. consistency relations/constraints may be contradicting

[Klare2018, Gleitze2017]

Option 1: Define relations between all pairs of metamodels

Multi-Model Consistency: Trees



Scenario:
Develop a system only with the ADL and Java

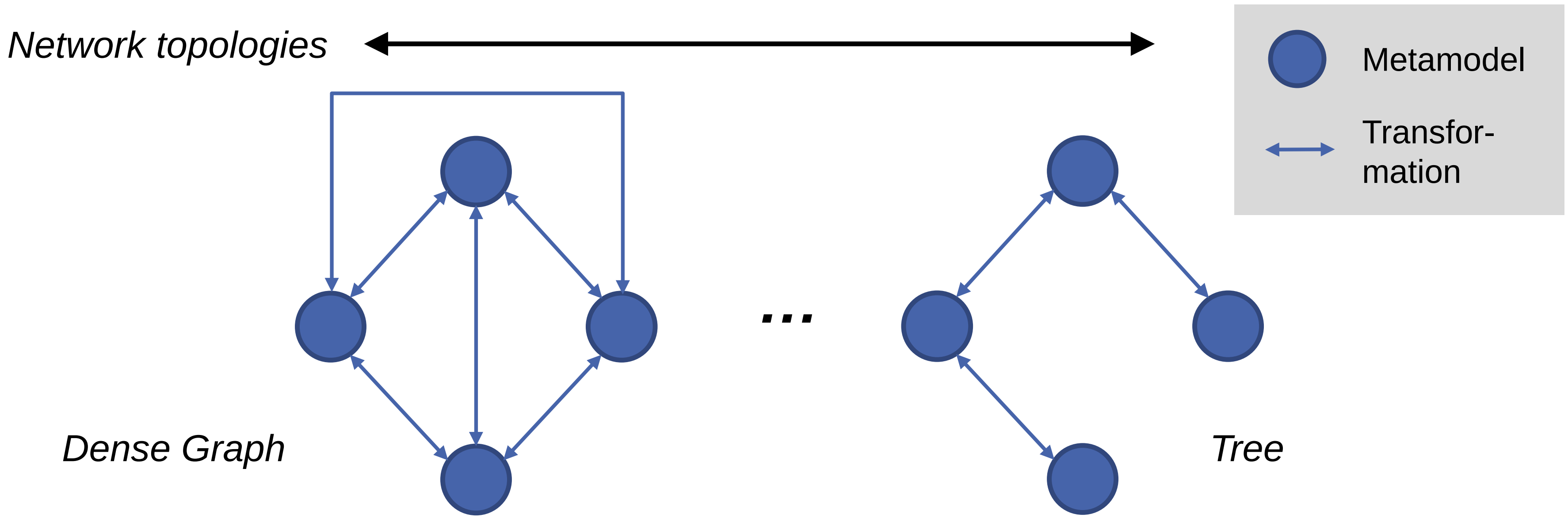
Bad *modularity*

i.e. no arbitrary metamodel selection without loosing consistency relations

[Klare2018, Gleitze2017]

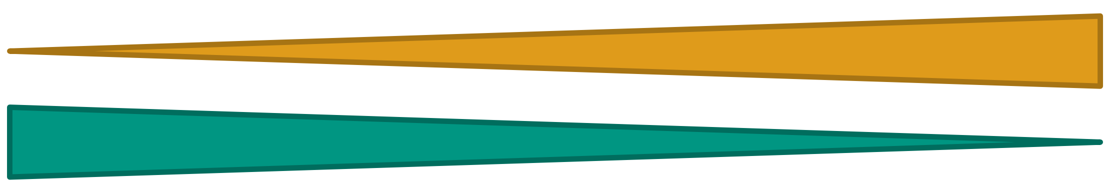
Option 2: Define relations between metamodels to form a tree

Trade-off: Compatibility vs. Modularity



Compatibility
(Relations/transformations do not contradict each other)

Maximize: $\theta(n^2)$ paths between each metamodel pair



Maximize: only one path between each metamodel pair

Modularity
(Possibility to select arbitrary metamodel subset without loosing consistency relations)

[Klare2018, Gleitze2017]

Contributions and Expected Benefits

Problem

Trade-off between *compatibility* and *modularity* in bidirectional transformation networks.

Idea

Resolve the trade-off between *compatibility* and *modularity* for consistency of multiple models by making common concepts of metamodels explicit.

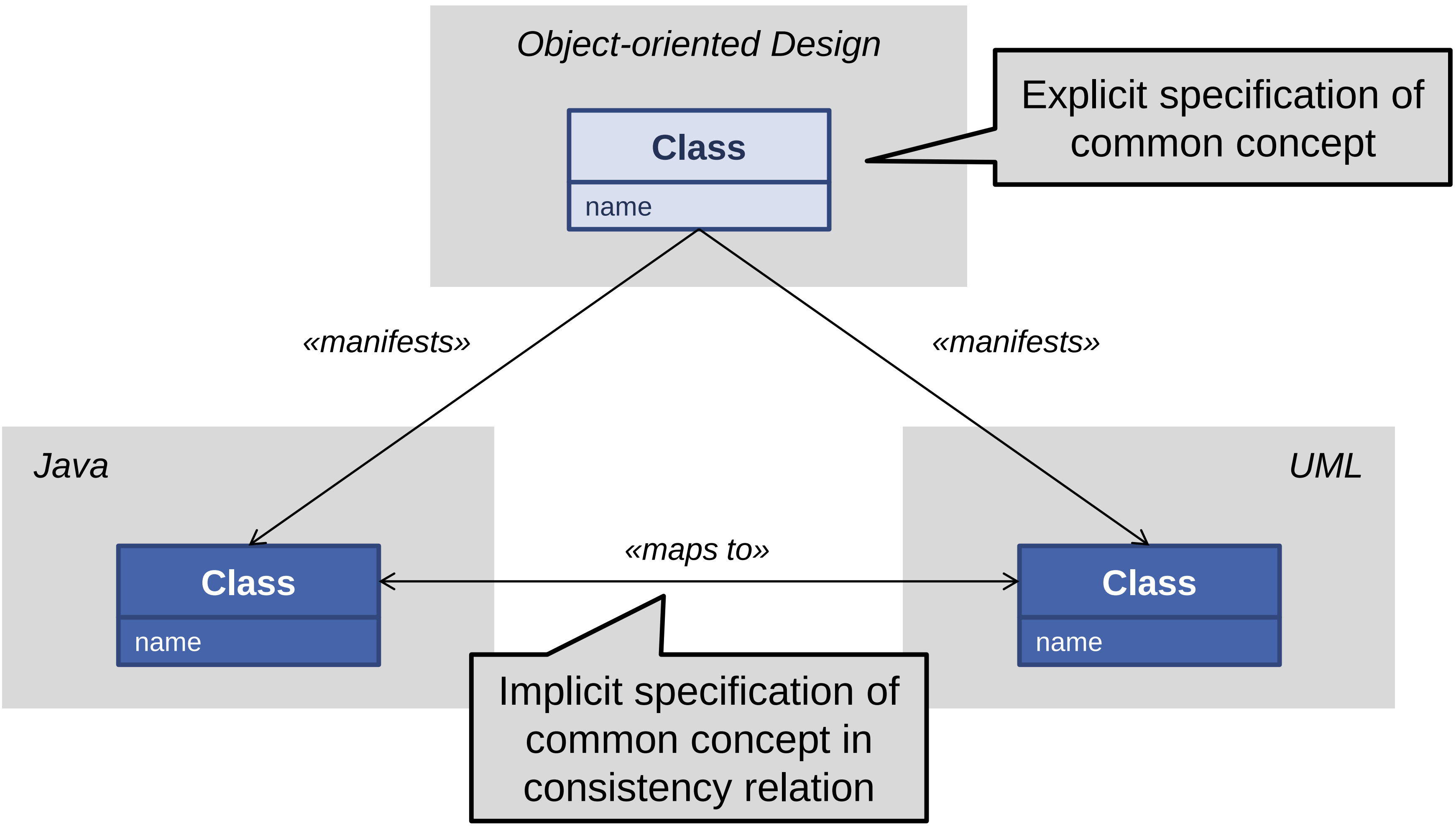
Contributions

- Commonalities Approach
- Commonalities Language
- Proof of Concept

Expected Benefits

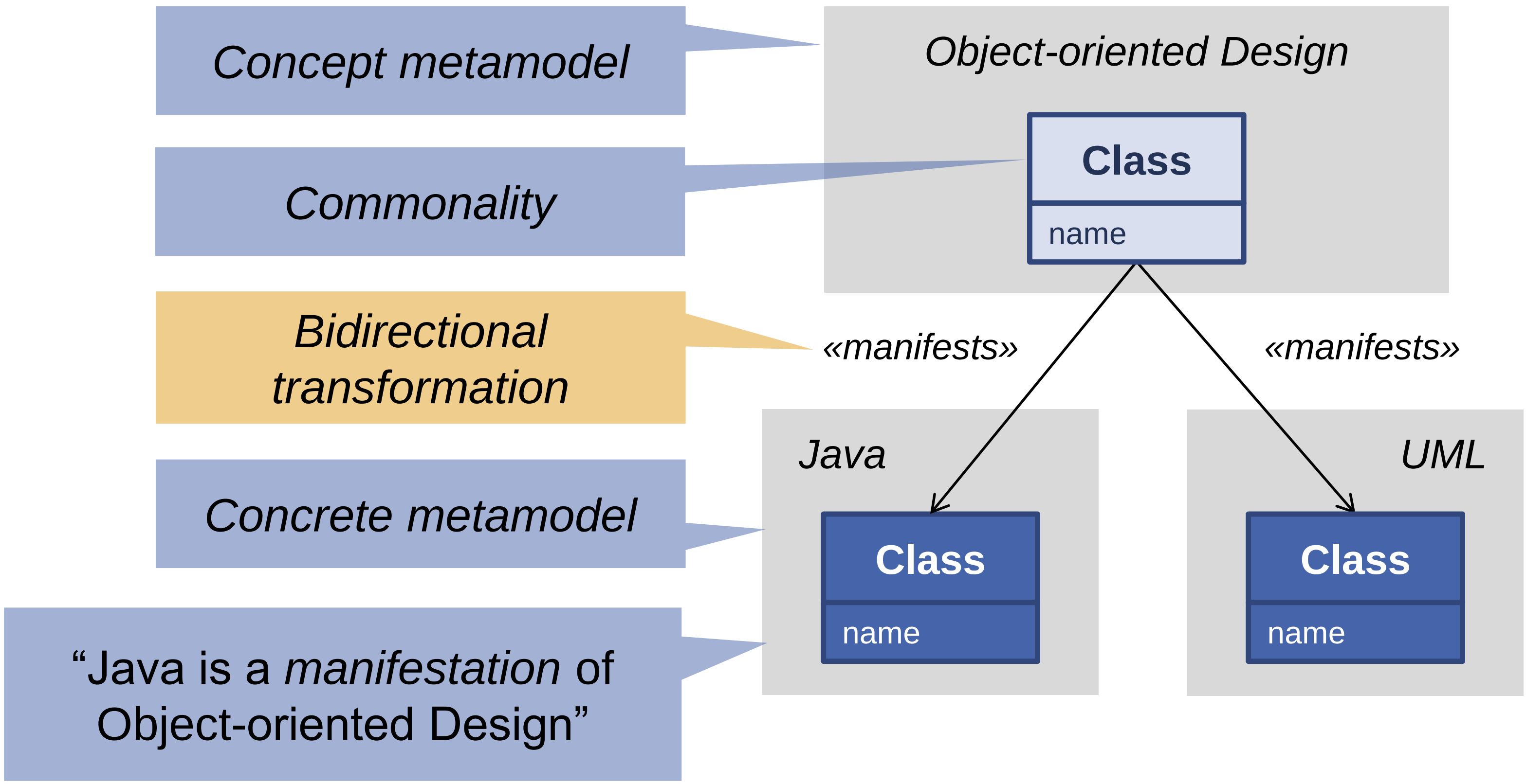
- Improved comprehensibility
- Reduced specification effort
- Improved compatibility and modularity

From Relations to Explicit Common Concepts



The Commonalities Approach

- Encode commonalities in metaclasses of a conceptual metamodel
- Represent common information in features of the conceptual metamodel



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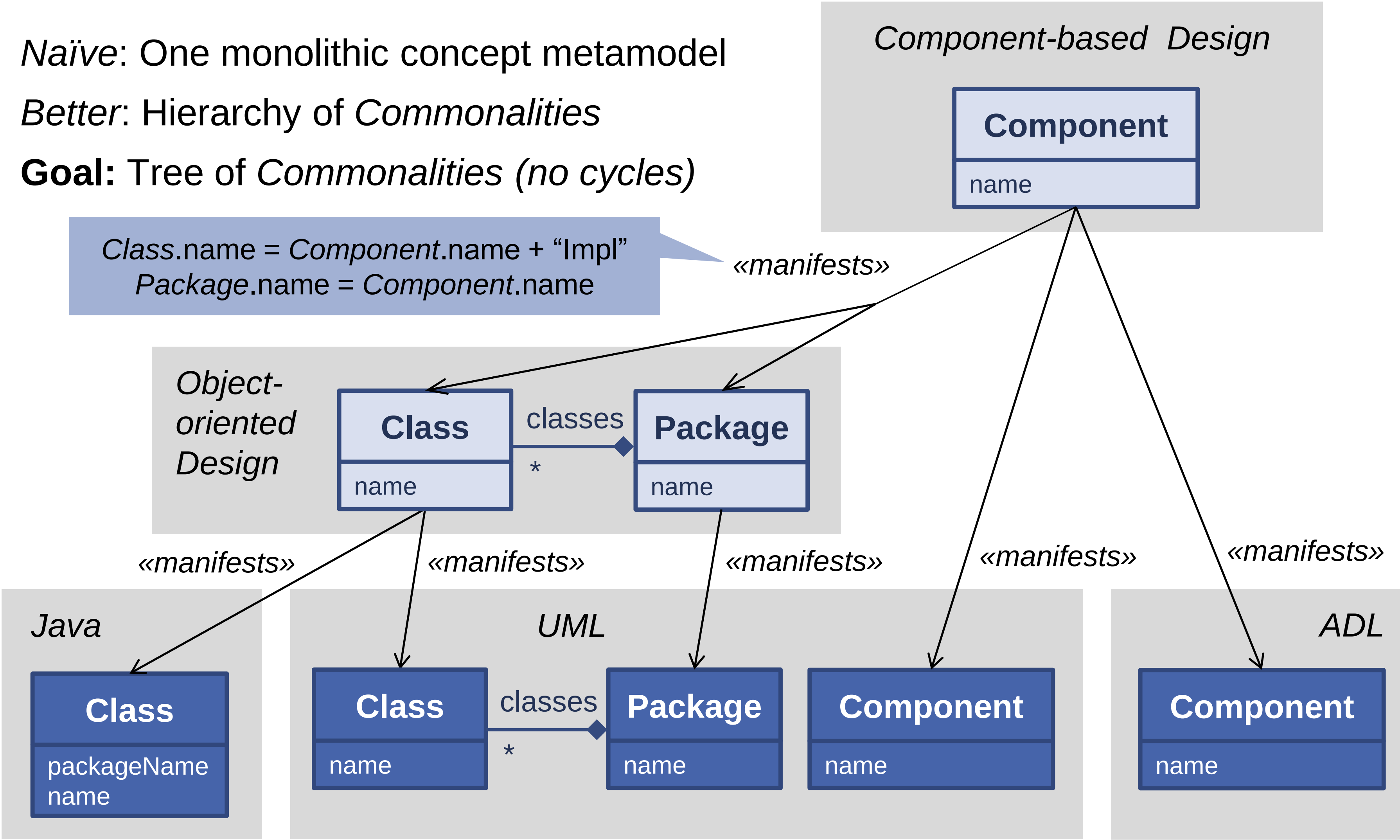
Hierarchic Composition of Commonalities

Naïve: One monolithic concept metamodel

Better: Hierarchy of *Commonalities*

Goal: Tree of *Commonalities (no cycles)*

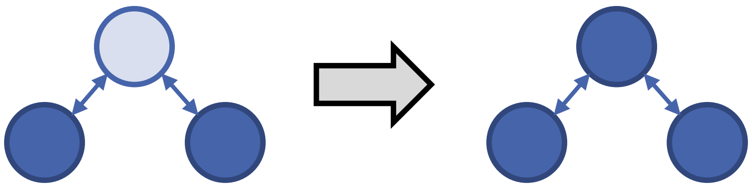


Design Decisions

Artifact Generation

(transparent to user)

Concept metamodels as additional metamodels



Concept metamodel → Metamodel
Commonality → Metaclass
Manifestation specification → Transformation

Alternative: Derive direct transformations between concrete metamodels

Benefits:

- Easy to achieve
- High expressiveness (*n*-ary relations)

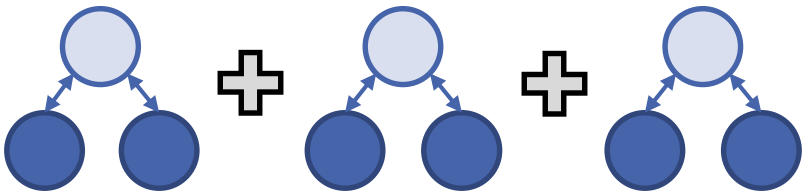
Drawback:

- Management of additional artifacts

Commonalities Specification

(visible to user)

Internal specification



Integrated definition of concept metamodels with manifestations

Decomposition dimension: Commonalities

Alternative: External specification (Decomposition dimension: Transformations)

Benefits:

- Easy to add Commonalities
- Improved locality / conciseness

Drawback:

- More difficult to add metamodels

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Commonalities Language

```
concept Components

commonality Component {
   with UML:Component
   with ObjectOrientation:(Class in Package)

   has name {
      = UML:Component.name
      = ObjectOrientation:Package.name
      = suffix(ObjectOrientation:Class.name, "Impl")
   }

   has subcomponent referencing Components:Component {
      = UML:Component.packagedElement
      = ObjectOrientation:Package.subpackages
   }

}
```

Concept metamodel

Commonality

Manifestation (Concrete)

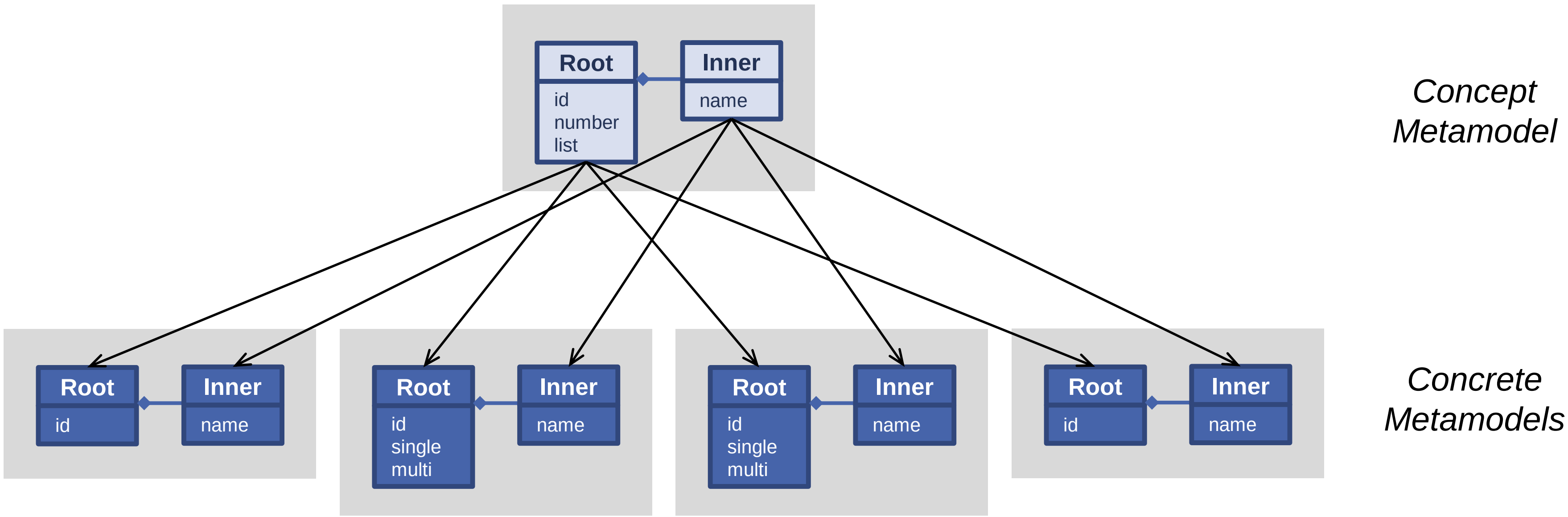
Manifestation (Concept)

Attribute Mapping

Reference Mapping

Proof of Concept

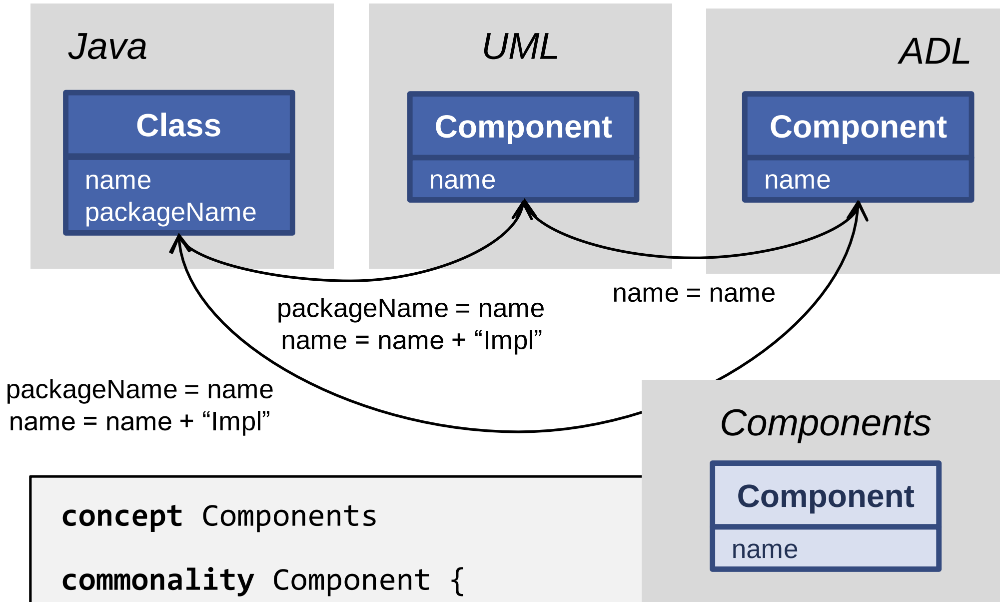
Case Study *(schematic)*



Feasibility

- Test cases performing all possible types of model modifications
- Correct propagation of all changes → indicator for functional correctness

Benefit: Comprehensibility



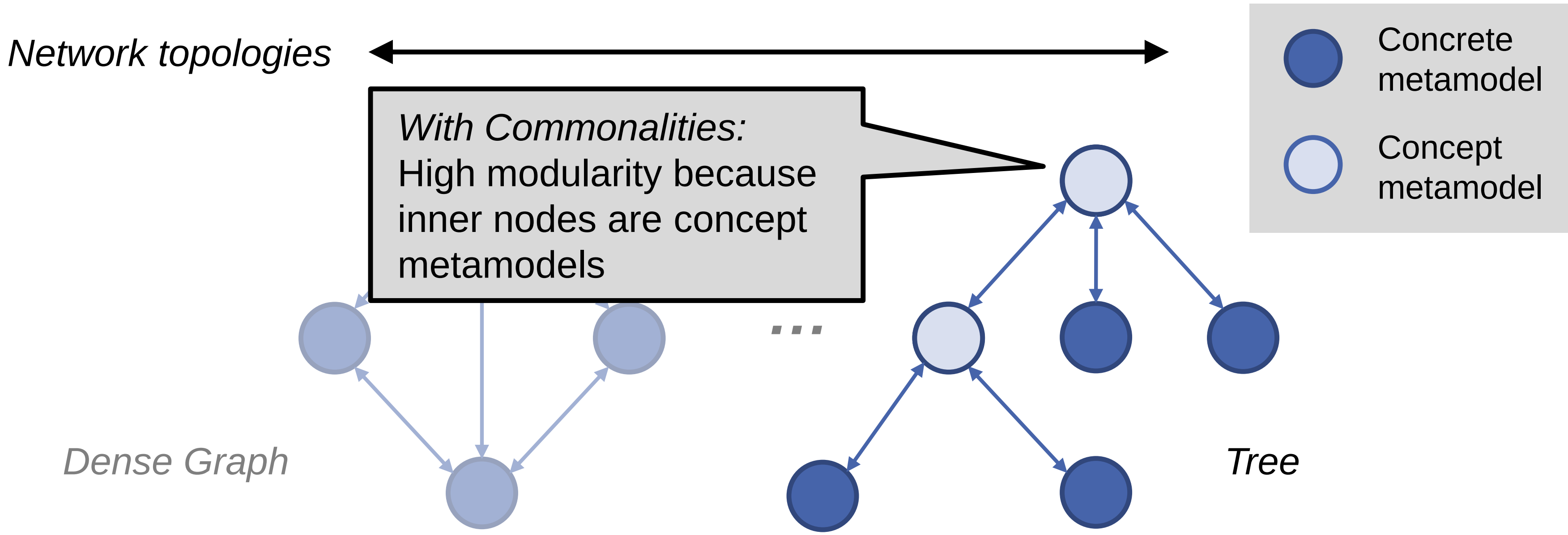

```
concept Components

commonality Component {
    with uml:Component
    with adl:Component
    with java:Class

    has name {
        = uml:Component.name
        = adl:Component.name
        = java:Class.packageName
        = suffix(java:Class.name, "Impl")
    }
}
```

```
relation UMLComponent2ADLComponent {
   componentName : String;
   domain uml component : Component {
     name = componentName;
   }
   domain adl component : Component {
      name = componentName;
   }
}
```

```
relation Class2ADLComponent {
   componentName : String;
   domain java class : Class {
     name = componentName + "Impl";
     packageName = componentName;
   }
   domain adl component : Component {
      name = componentName;
   }
}
```

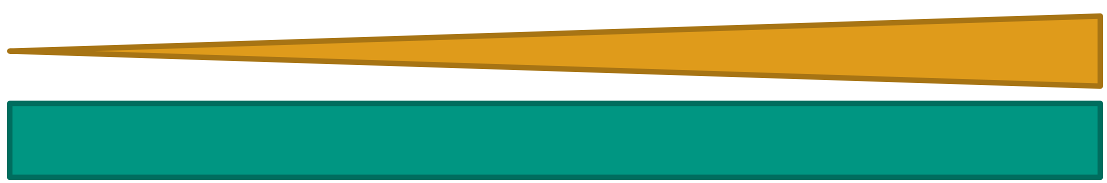
```
relation Class2UMLComponent {
   componentName : String;
   domain java class : Class {
     name = componentName + "Impl";
     packageName = componentName;
   }
   domain uml component : Component {
      name = componentName;
   }
}
```

Benefit: Compatibility and Modularity



Compatibility
(Relations/transformations do not contradict each other)

Maximize: only one path between each metamodel pair



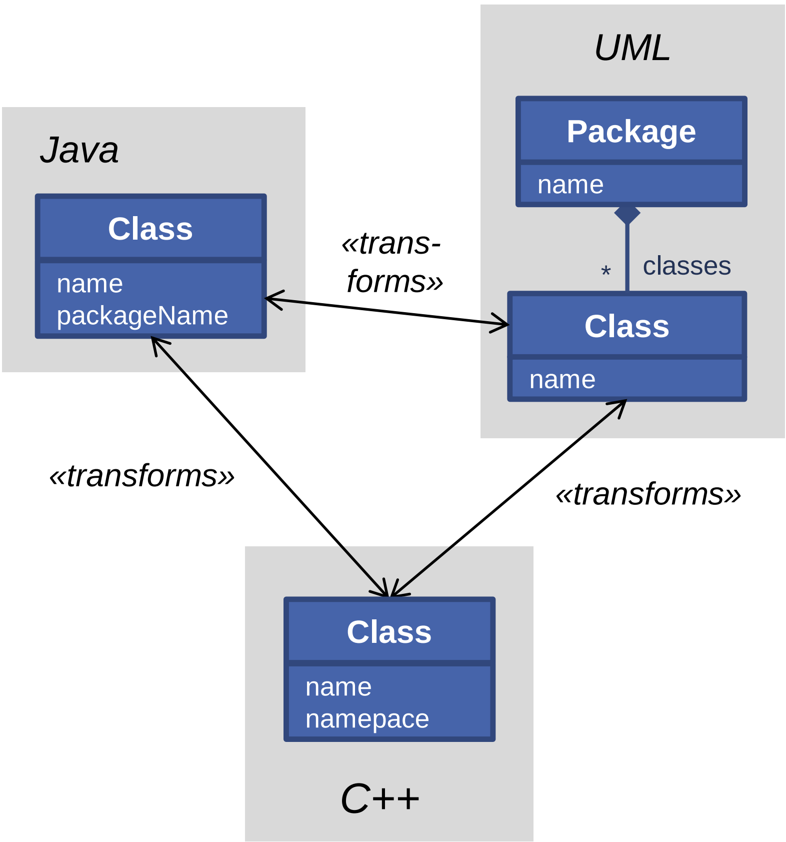
Maximize: $\theta(n^2)$ paths between each metamodel pair

Modularity
(Possibility to select arbitrary metamodel subset without loosing consistency relations)

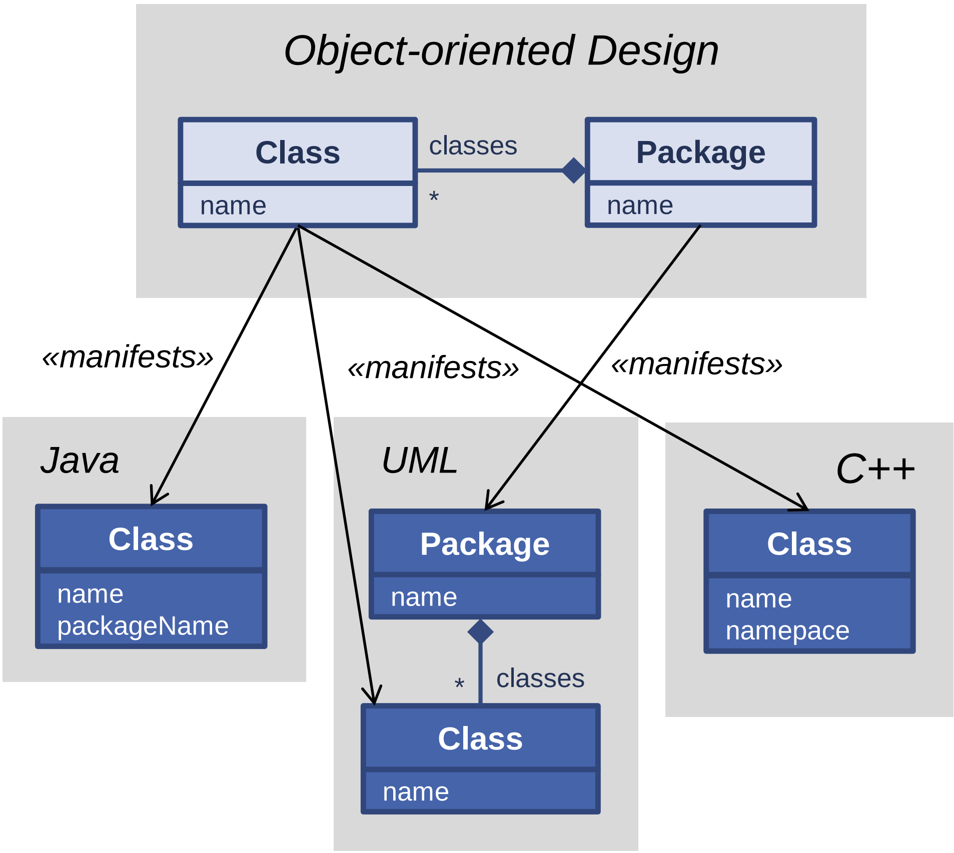
[Klare2018, Gleitze2017]

Benefit: Specification Effort

Ordinary Transformations



Commonalities

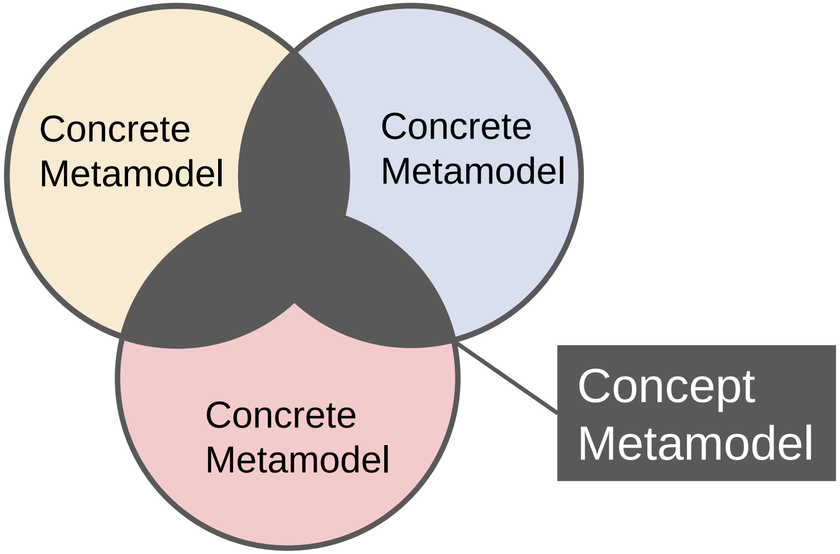


Number of relations grows linearly with *Commonalities* but quadratically with transformations

Comparison with the SUM(M) Approach

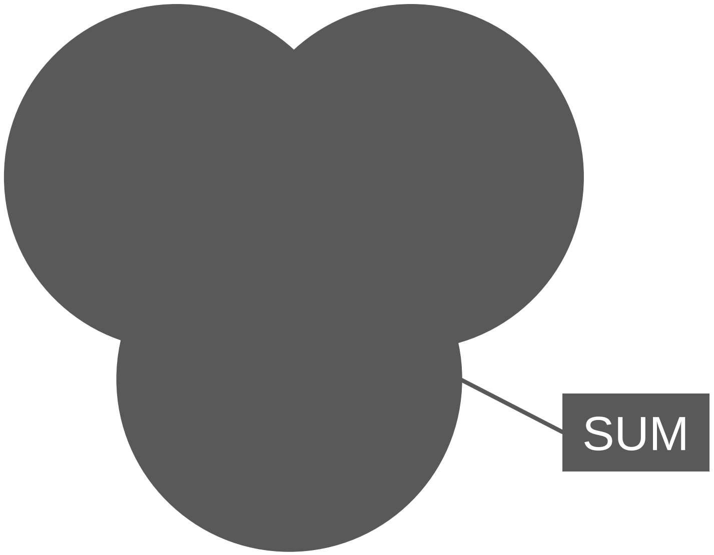
Commonalities Approach

Concept metamodel is union of pairwise intersections of concepts



SUM(M) Approach

SUM is union of concepts of all metamodels



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Related Work

Commonalities Approaches

Practical approaches

- Sophisticated commonalities language [Gleitze2017]
- Role-oriented SUM [Werner2018]
- Domain-specific: DUALLy [Malavolta2010, Eramo2012]

Theoretic considerations

- Multiary Delta Lenses [Diskin2018]
- Commonalities for *n*-ary constraints [Stünkel2018]

Multidirectional Transformations and Networks of Bidirectional Transformations

- Dagstuhl Seminar [Cleve2019]
- Constraint decomposition problems [Stevens2017]
- Language-specific: QVT-R [Macedo2014], TGG [Trollmann2016]

Conclusion and Future Work

Goal

Resolve the trade-off between *compatibility* and *modularity* for multi-model consistency.

Contributions

Commonalities Approach

- *Concept metamodels* of *Commonalities*
- Manifestation relations
- Hierarchic composition of Commonalities

Commonalities Language

- Design options
  - Artifact generation
  - Commonalities specification
- Proof of concept implementation

Expected Benefits

General	Comprehensibility ↑
Multi-model case	Effort ↓ Errors ↓ Modularity ↑

Future Work

- Extend language capabilities
- Evaluate benefits
  - *Applicability*: case study
  - *Comprehensibility*: experiment
- Validate practicality of hierarchic composition

Bib: Commonalities

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[Stevens2017] P. Stevens, “Bidirectional Transformations in the Large,” in *2017 ACM/IEEE 20th International Conference on Model Driven Engineering Languages and Systems (MOD-ELS)*, 2017, pp. 1–11.

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[Eramo2008] R. Eramo, A. Pierantonio, J. R. Romero, and A. Valle- cillo, “Change Management in Multi-Viewpoint System Using ASP,” in *Enterprise Distributed Object Computing Conference Workshops*, 2008, pp. 433–440.

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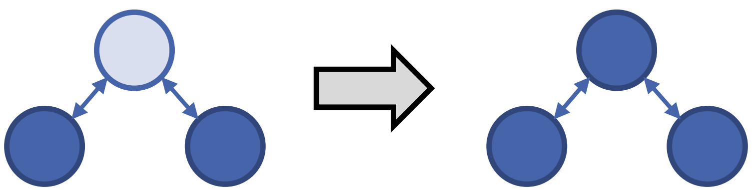
Design Decision: Artifact Generation

Artifact generation is transparent to user

Concept metamodels as additional metamodels

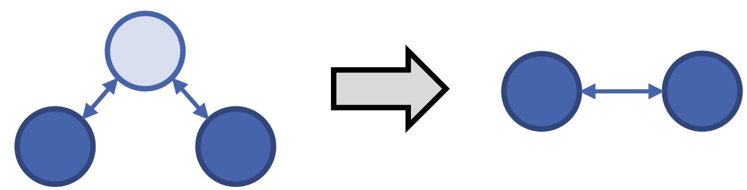


Concept metamodel → Metamodel
Commonality → Metaclass
Relation specification → Transformation

Benefits:

- Easy to achieve
- High expressiveness (*n*-ary relations)

Transformations between concrete metamodels



Indirect relations across concept metamodels → Transformations between pairs of concrete metamodels

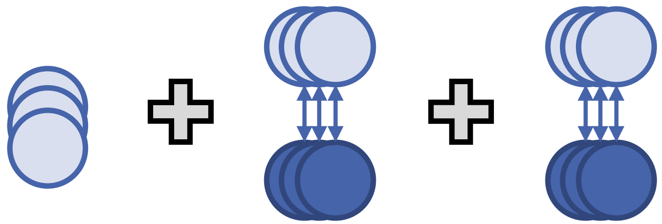
Benefits:

- No management of additional artifacts
- Easier to understand direct relations

Design Decision: Commonalities Specification

Commonalities specification is visible to user

External specification



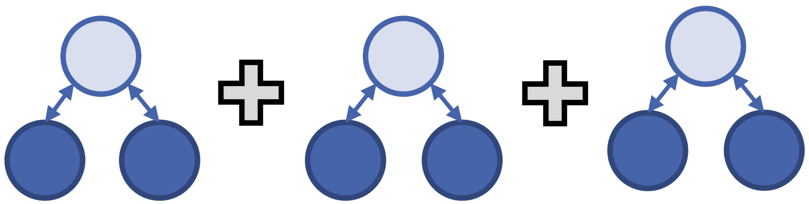
Independent definition of concept metamodels and transformations

Decomposition dimension: Transformations

Benefits:

- Easy to add concrete metamodels
- Reuse existing tooling

Internal specification



Integrated definition of concept metamodels with manifestations

Decomposition dimension: Commonalities

Benefits:

- Easy to add Commonalities
- Improved locality / conciseness

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Operators in the Commonalities Language

- The Commonalities language can be extended by operators that allow bidirectional propagation of information, e.g. ***`in`*** and ***`suffix`***
- To have well-defined bidirectional transformations, operators must be
  - Correct
  - Hippocratic
  - Undoable