Type Systems for Domain-specific Languages

ATPS Workshop 2013

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Institut für Informatik

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Large DSL Project MENGES [MEG09]

- Goal: DSL for railway control centers
- DSLs for various purposes
- Target languages for PLC [IEC03]
- But one XML output file (PLCOpen.xml)

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Agile grammar development

1. Domain analysis
2. Language development
3. Evaluation with users and case studies
4. Improving domain knowledge
5. goto 2

Problems

- Development of semantic checks

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- Mapping of source to target language
  - data structures and
  - expressions

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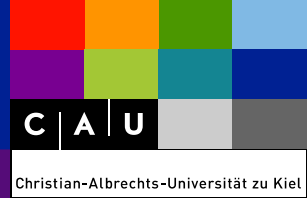
- Incomplete generators
- Unmaintainable generator after 2 years



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- Development of semantic checks
- Mapping of source to target language
  - data structures and
  - expressions
- Generator composition

Result

- Incomplete generators
- Unmaintainable generator after 2 years
- Language evolution complicated

Question How could we improve generator development?

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Idea

- Look into compiler development techniques
- Adapt techniques for DSL development
- Integrate with Xtext [AF11]

Xtext/TS [1]

- Type system framework
- DSL to write type checker
- Compact notation
- Limited typing features

[1] http://code.google.com/a/eclipselabs.org/p/xtext-typesystem/
[2] http://xsemantics.sourceforge.net/

Xtext/TS [1]

- Type system framework
- DSL to write type checker
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XSemantics [2]

- DSL to define type systems
- Rich syntax
- Compact notation
- Uses type system terminology (judgement, rule, . . .)

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Features

- Xtext-based expression framework
- Uses Java type system
- Provides Java type checking
- Provides partial code generation

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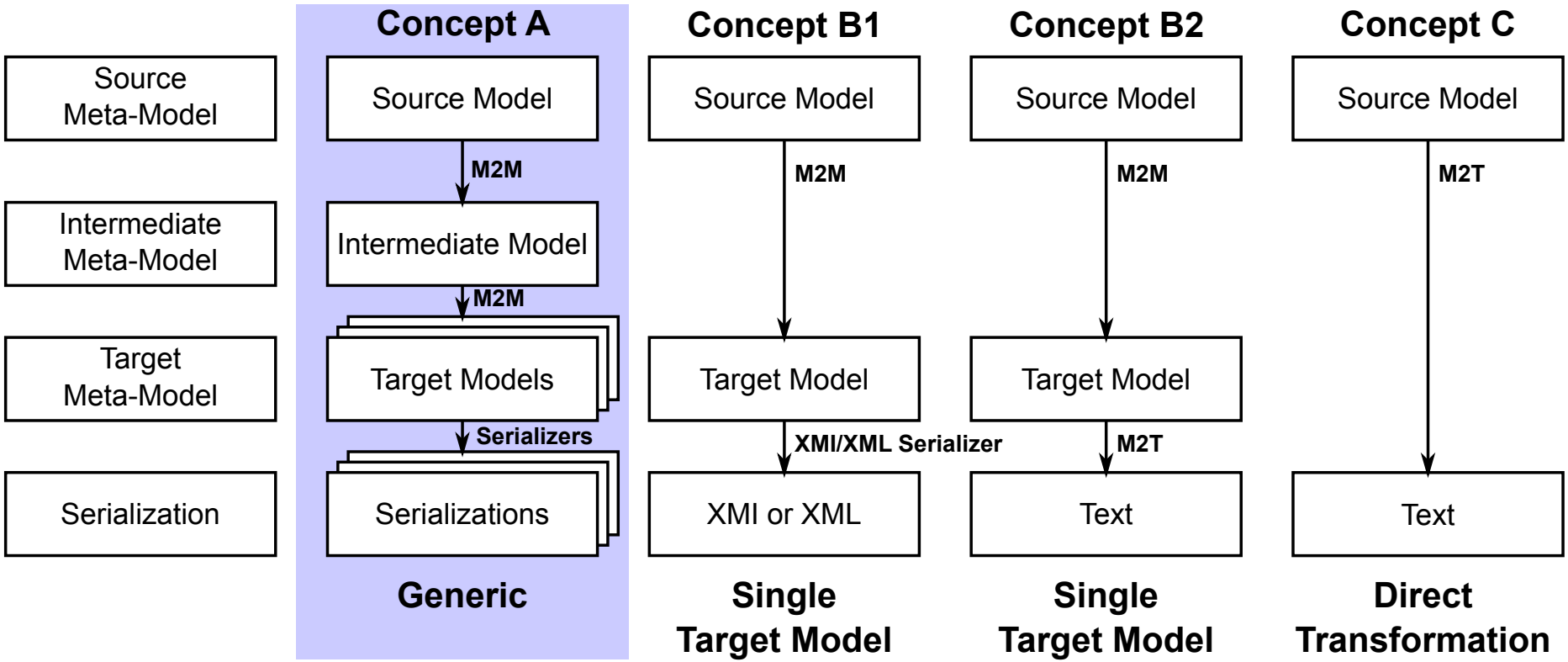
Limitations

- Works only with Java
- Non Java-types must be added by hand


Source Meta-Model
Intermediate Meta-Model
Target Meta-Model
Serialization
Concept A
Source Model
M2M
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Target Models
Serializers
Serializations
Generic
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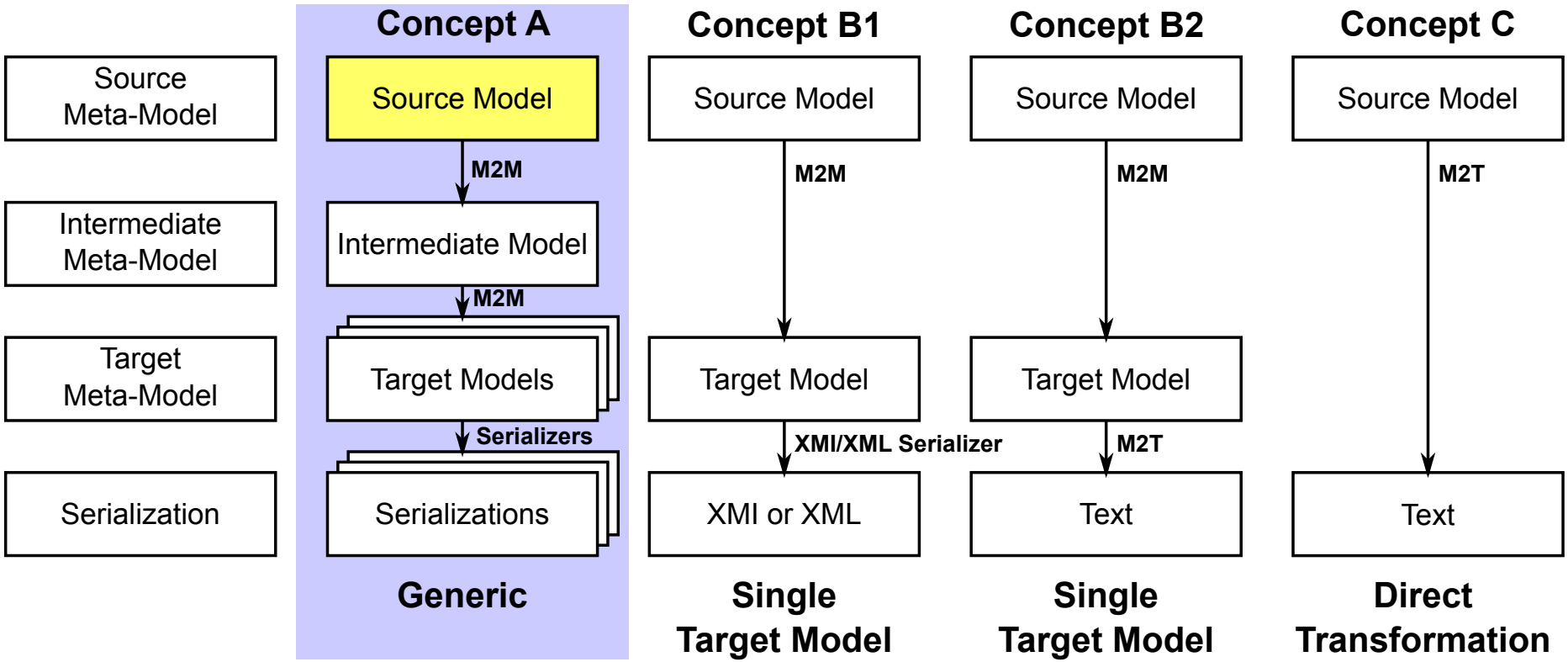
Direct Transformation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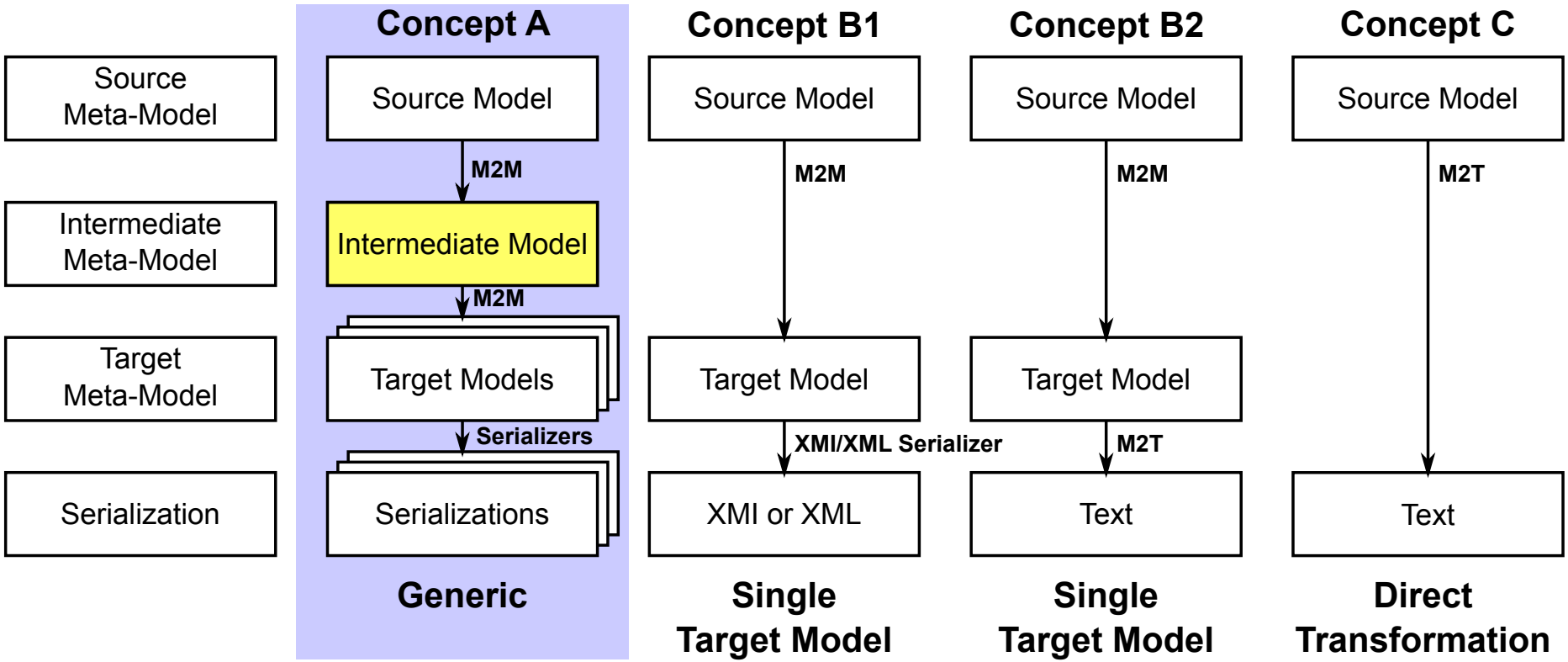
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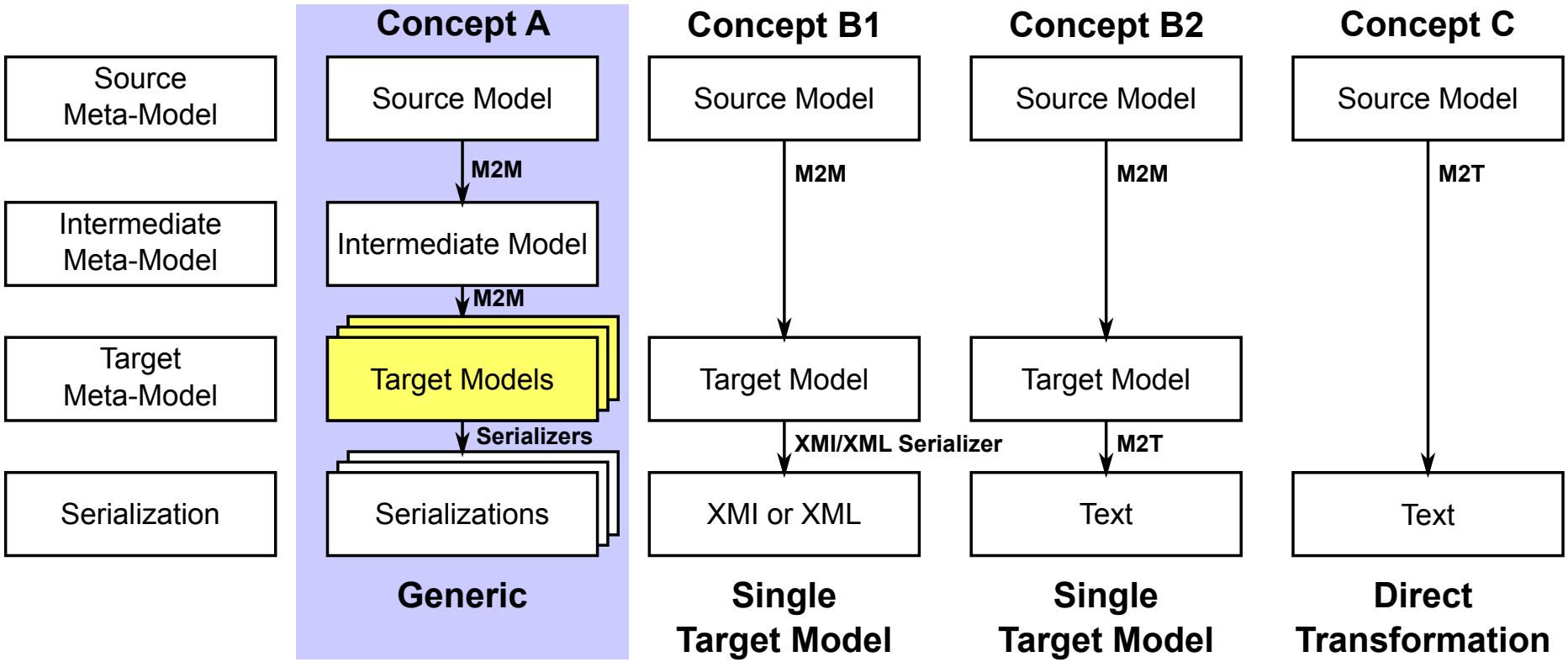
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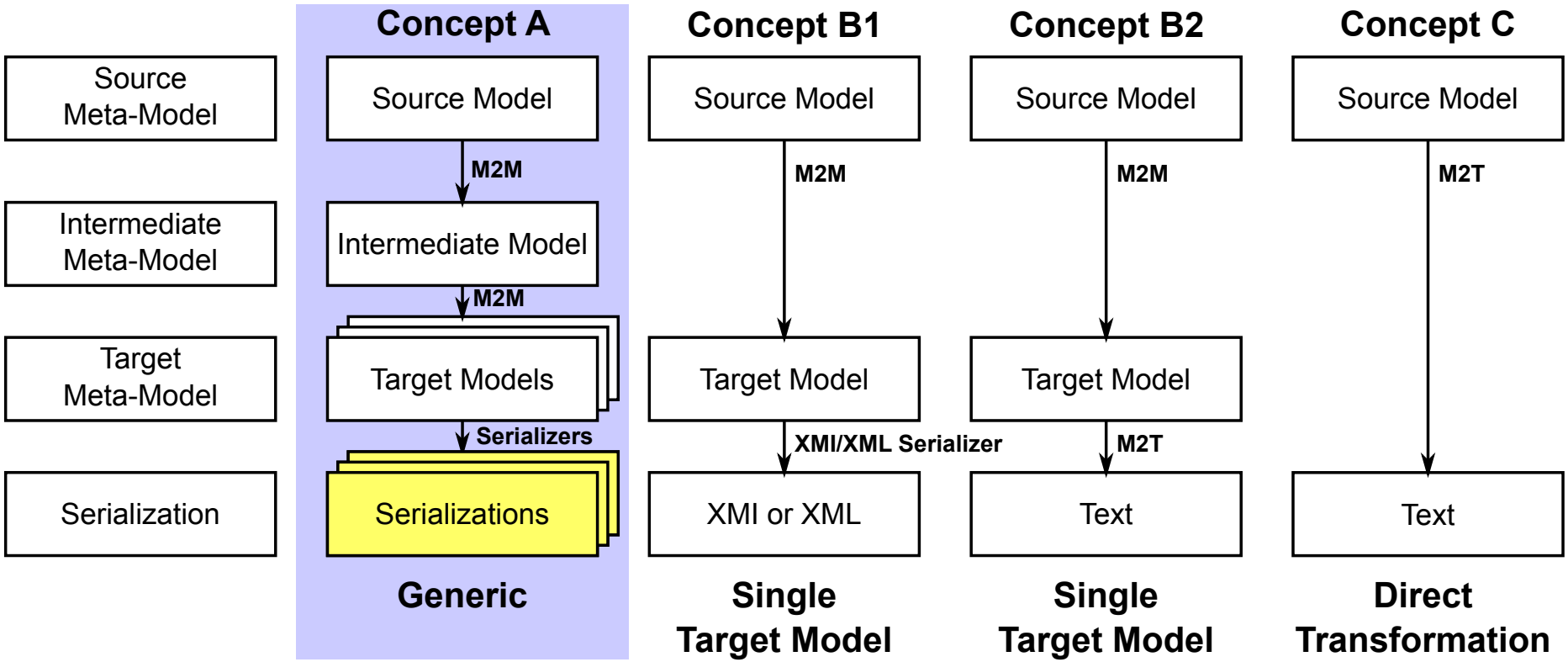
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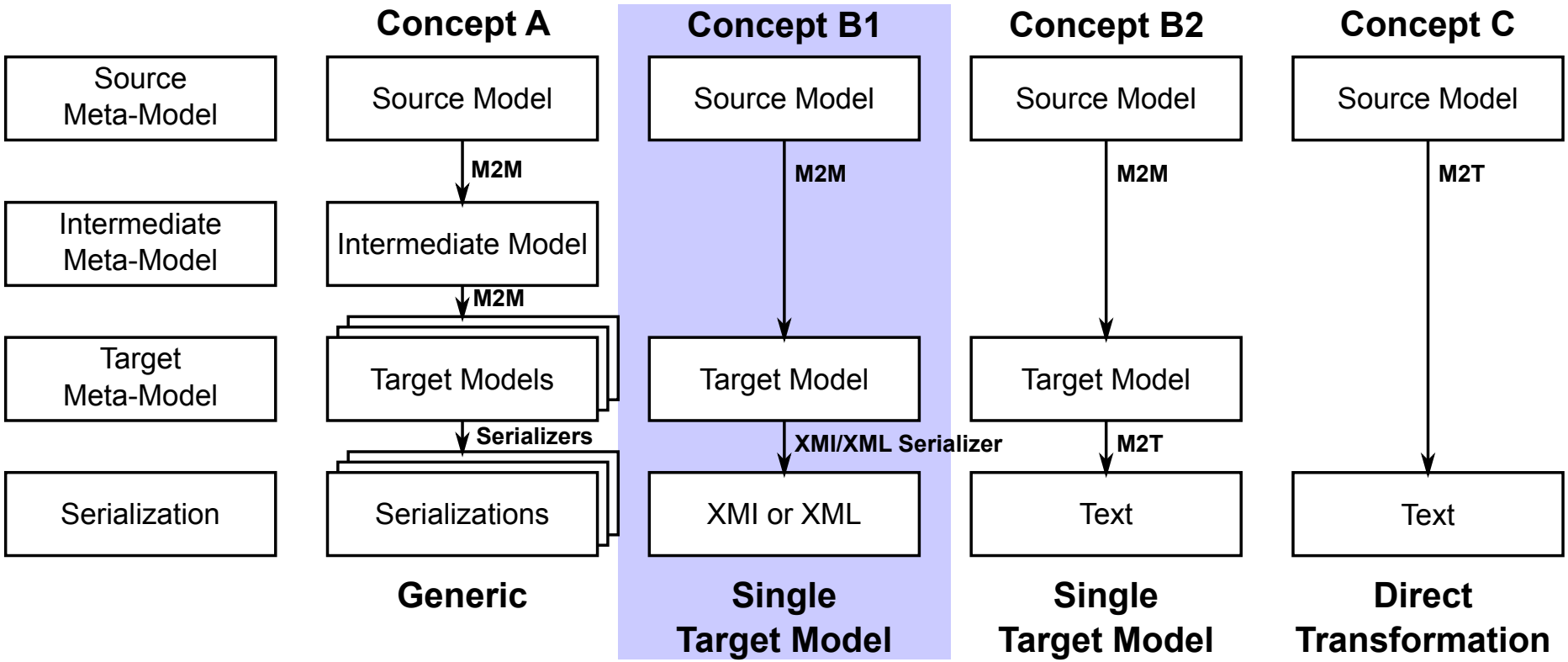
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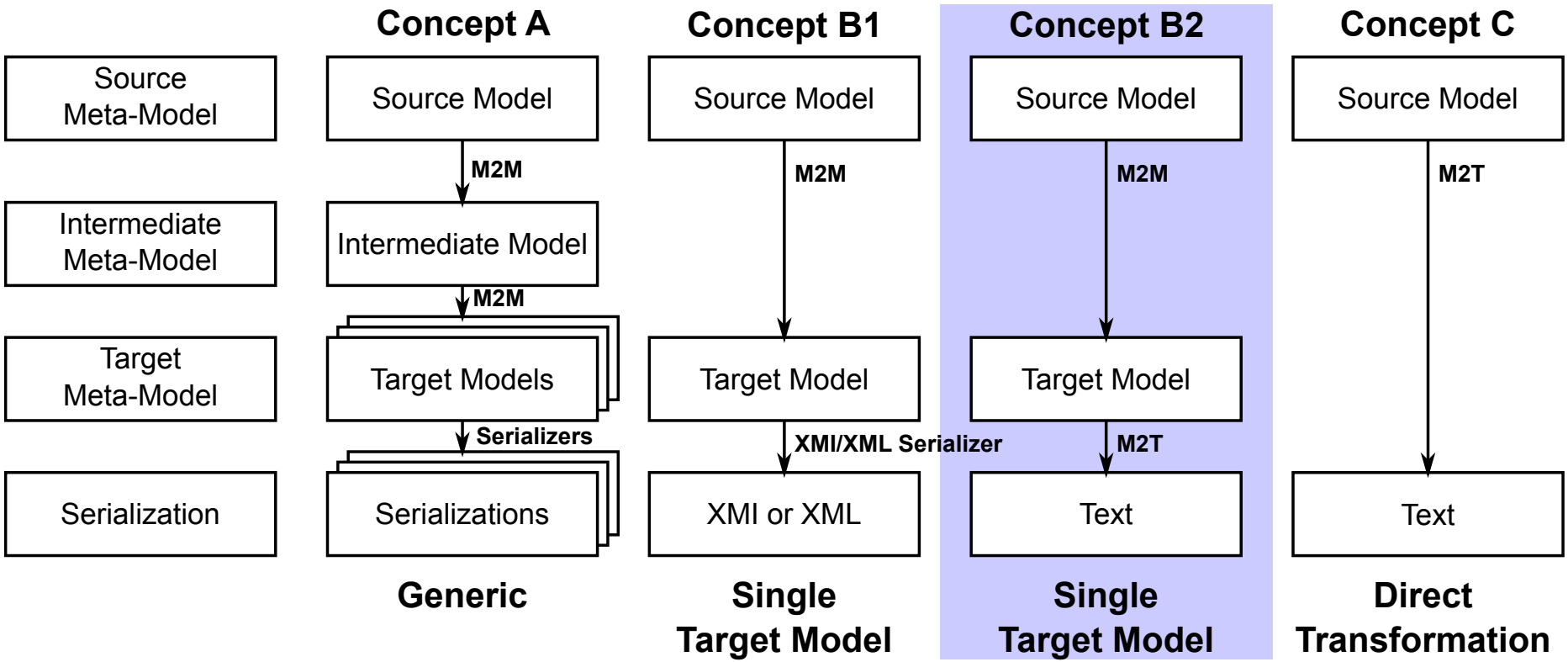
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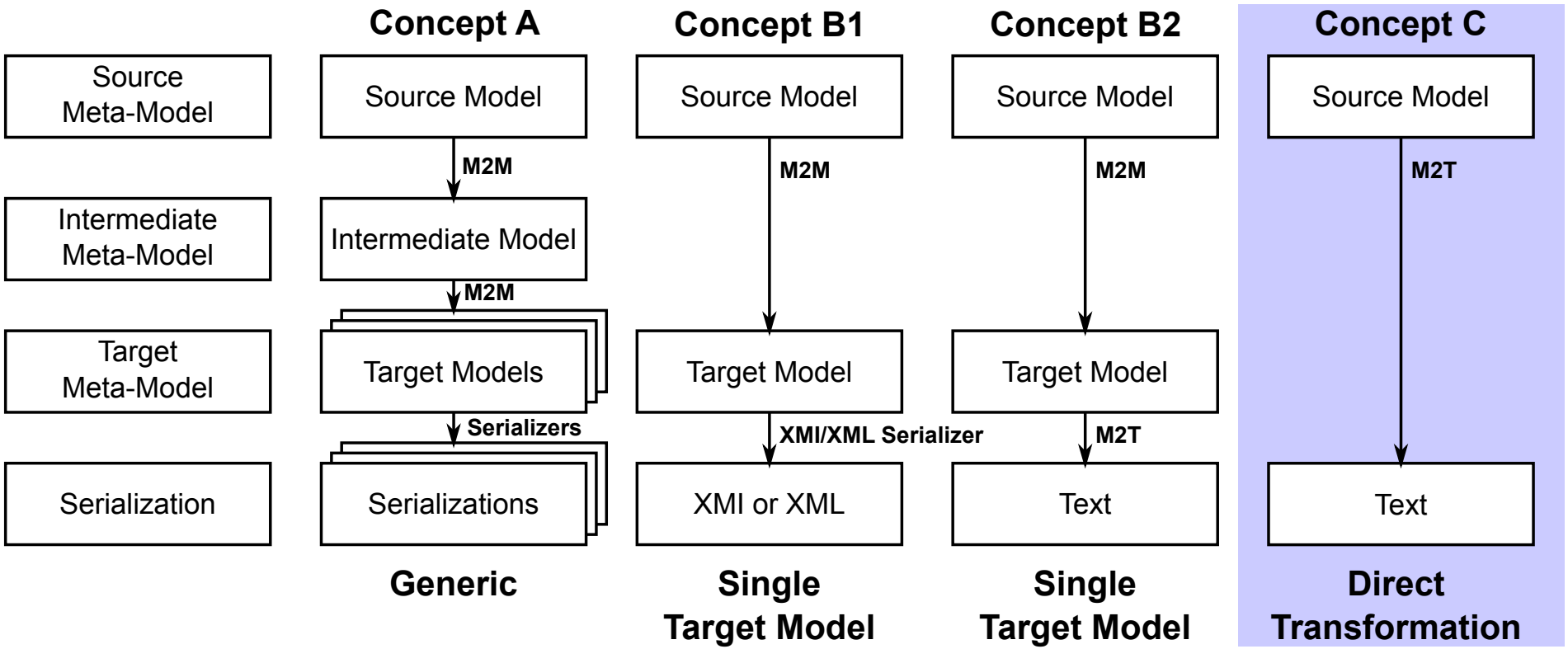
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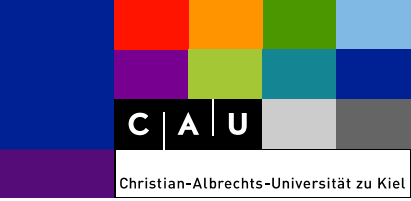

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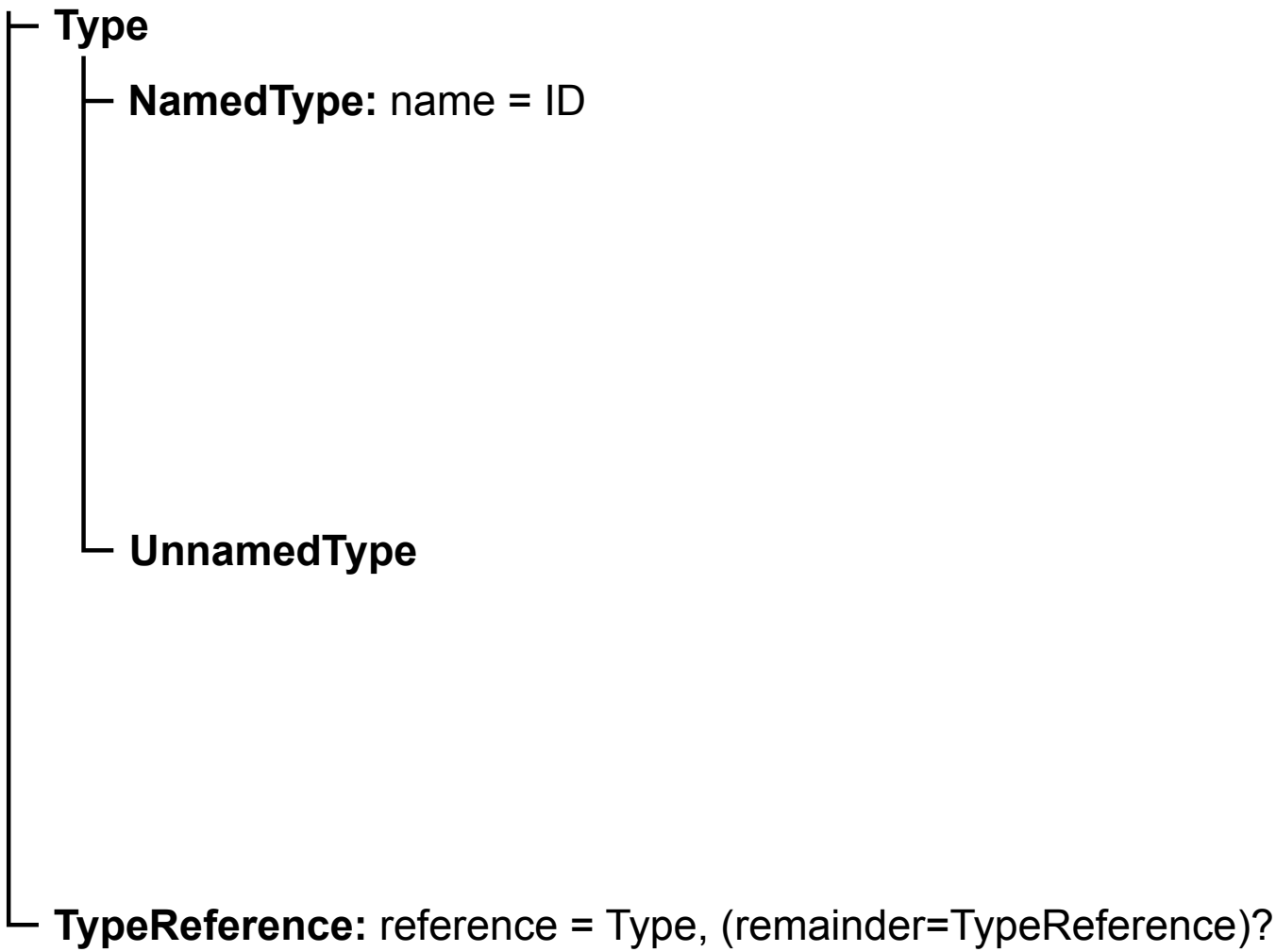
for nested type structures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NamedType: name = ID
UnnamedType
TypeReference: reference = Type, (remainder=TypeReference)?

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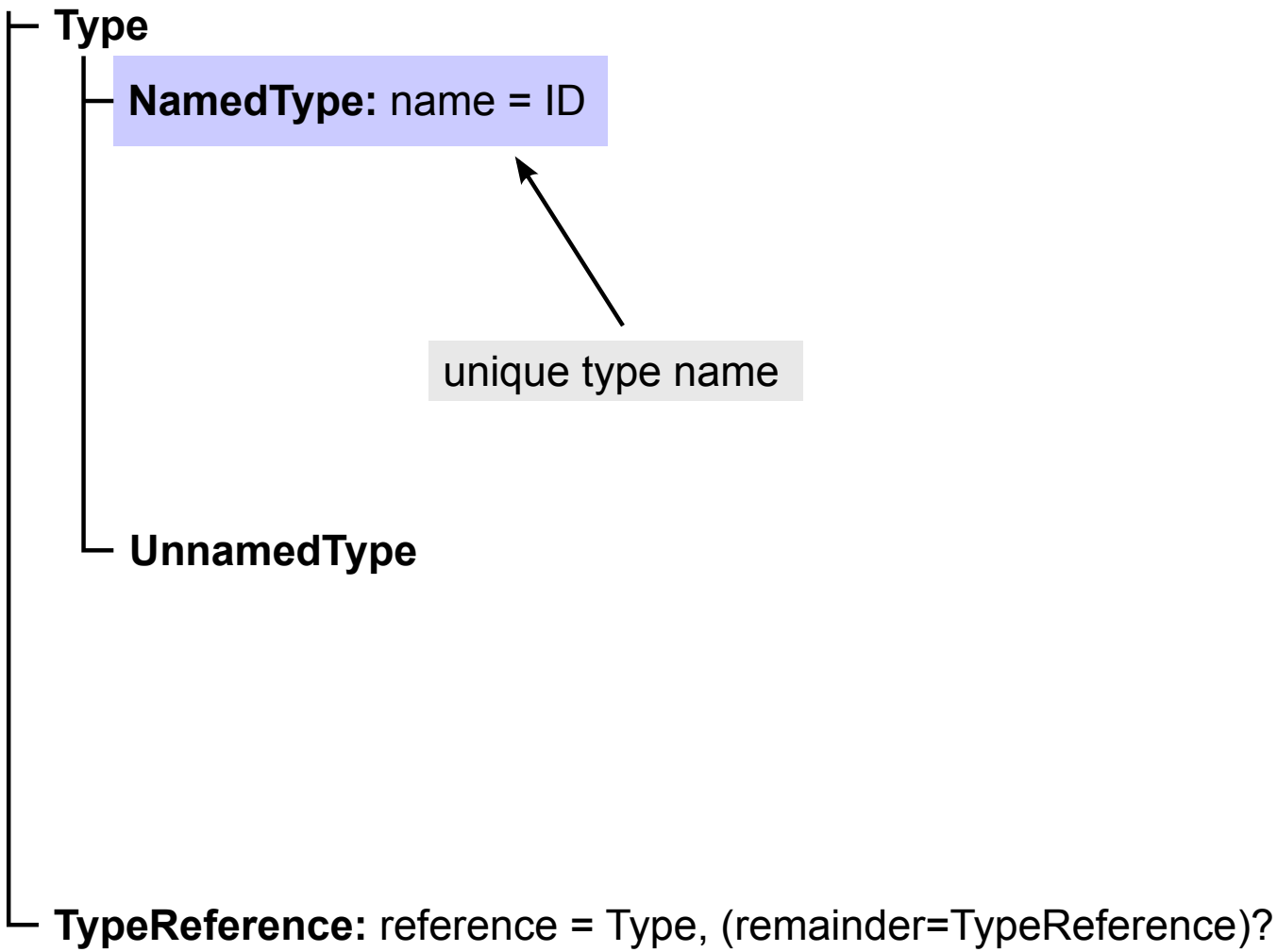
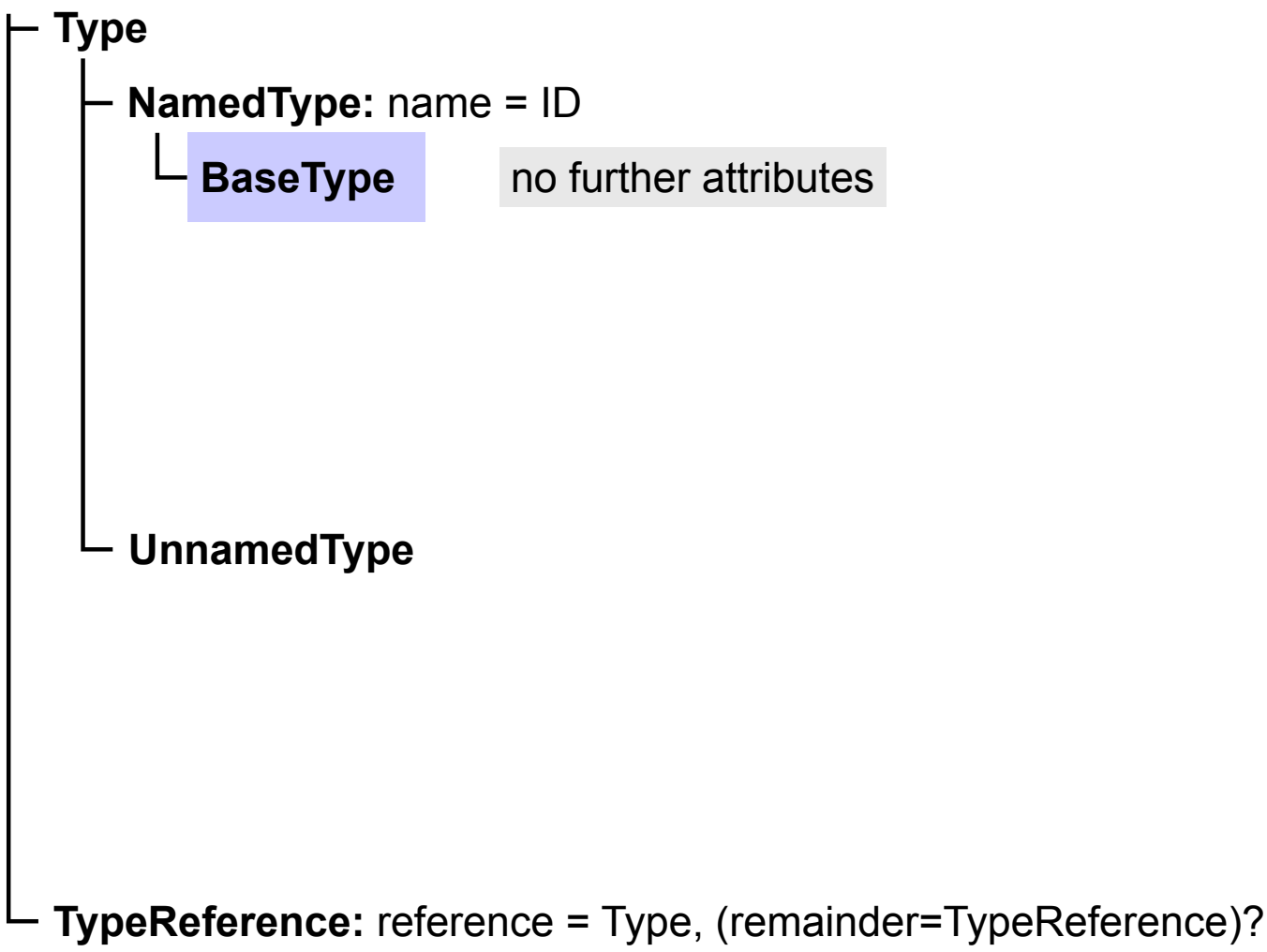
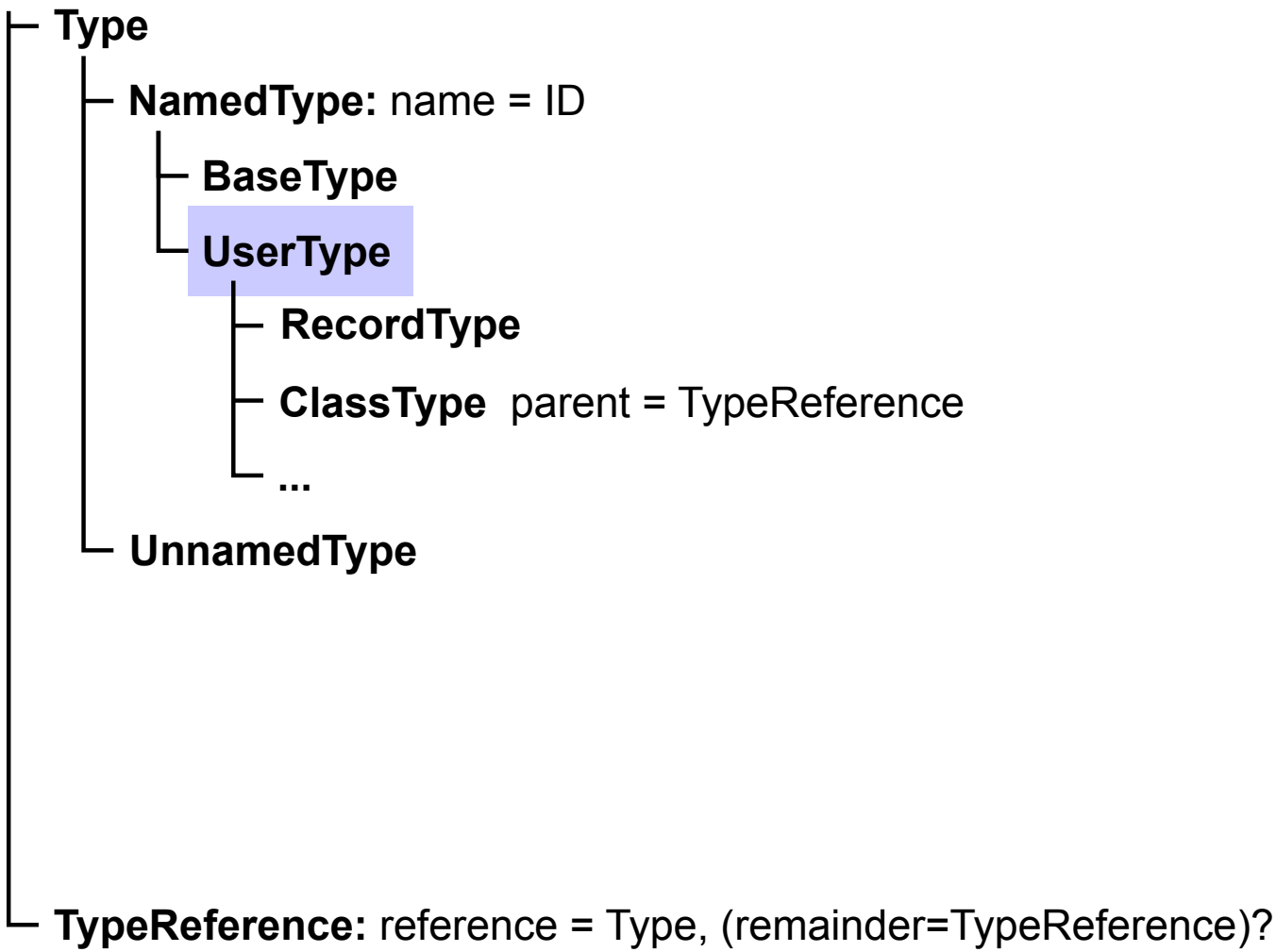
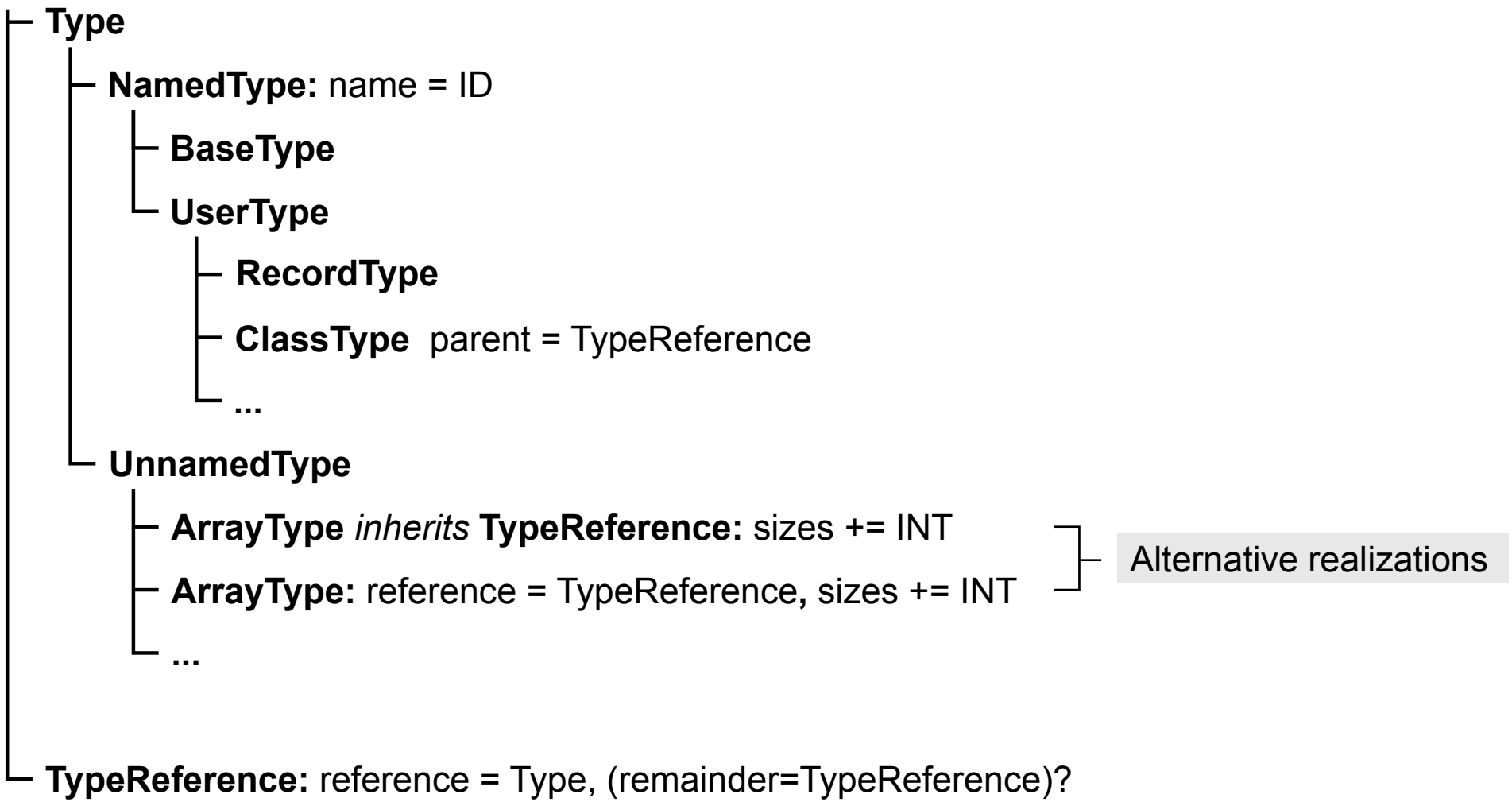

Type
NamedType: name = ID
unique type name
UnnamedType
TypeReference: reference = Type, (remainder=TypeReference)?


Type
NamedType: name = ID
BaseType
no further attributes
UnnamedType
TypeReference: reference = Type, (remainder=TypeReference)?


Type
NamedType: name = ID
BaseType
UserType
RecordType
ClassType parent = TypeReference
...
UnnamedType
TypeReference: reference = Type, (remainder=TypeReference)?


Type
NamedType: name = ID
BaseType
UserType
RecordType
ClassType parent = TypeReference
...
UnnamedType
ArrayType inherits TypeReference: sizes += INT
ArrayType: reference = TypeReference, sizes += INT
...
Alternative realizations
TypeReference: reference = Type, (remainder=TypeReference)?

Enumeration Base type declaration

```
public enum BaseTypes {
    BOOLEAN, INT, FLOAT, STRING; /* base types */

    public String lowerCaseName() {
        return this.name().toLowerCase();
    }
}
```

From our example application

`http://build.se.informatik.uni-kiel.de/de.cau.cs.se.lad.git`

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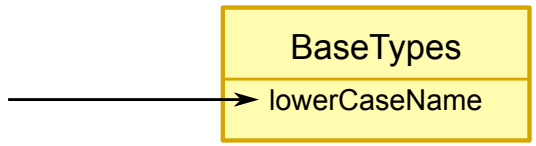

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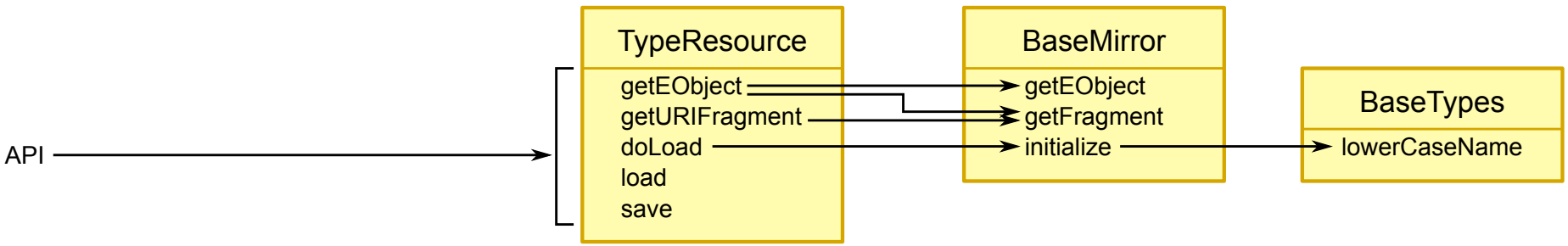

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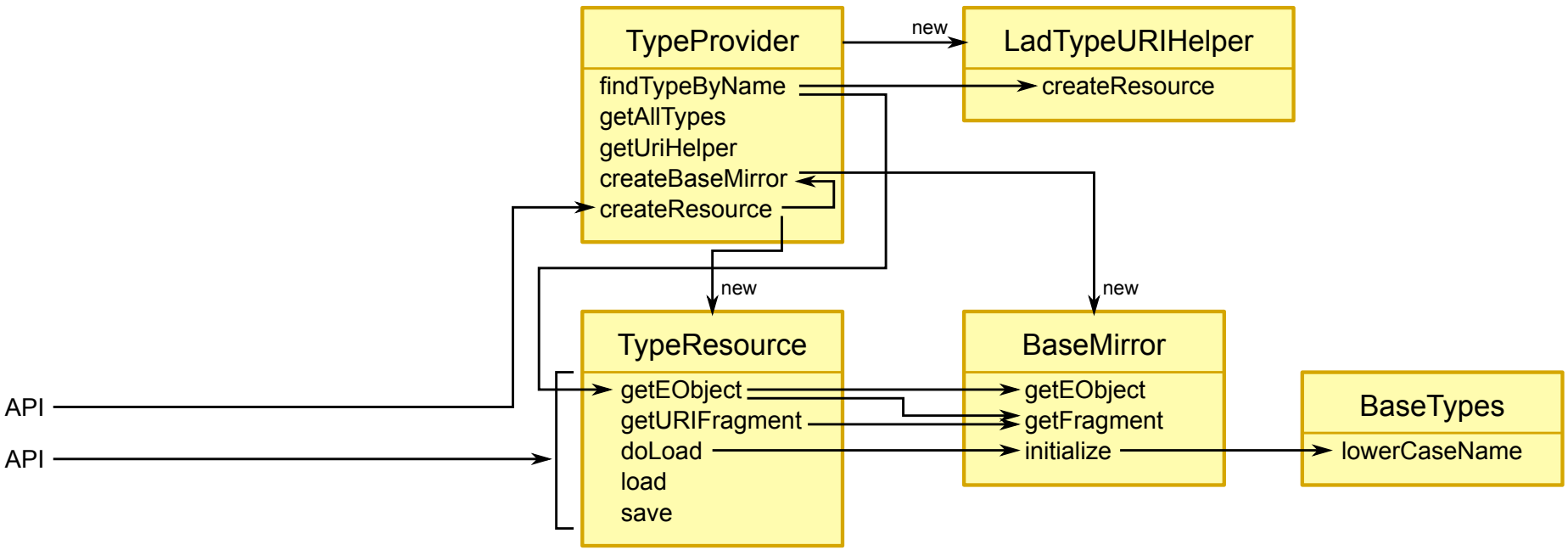

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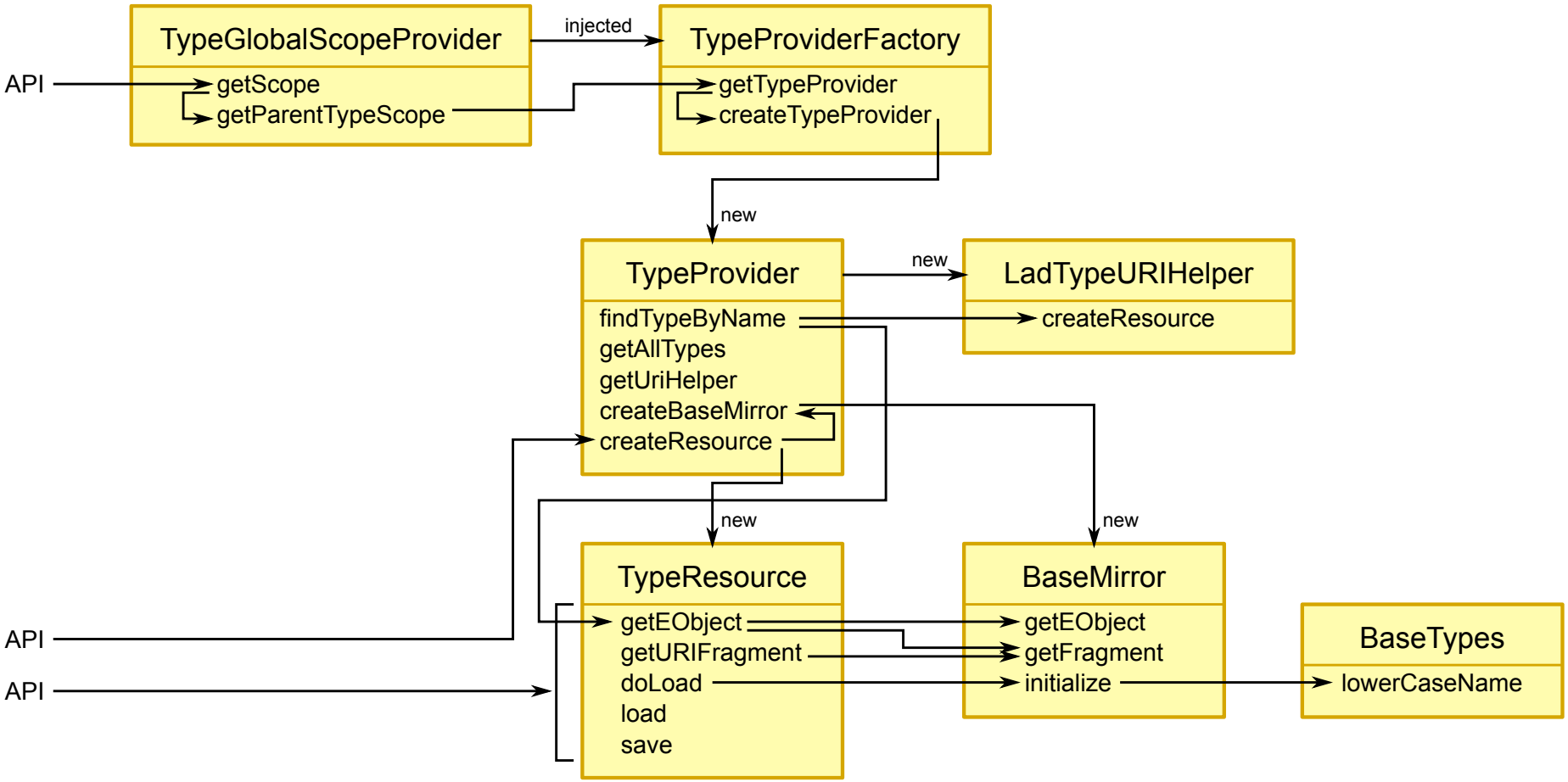

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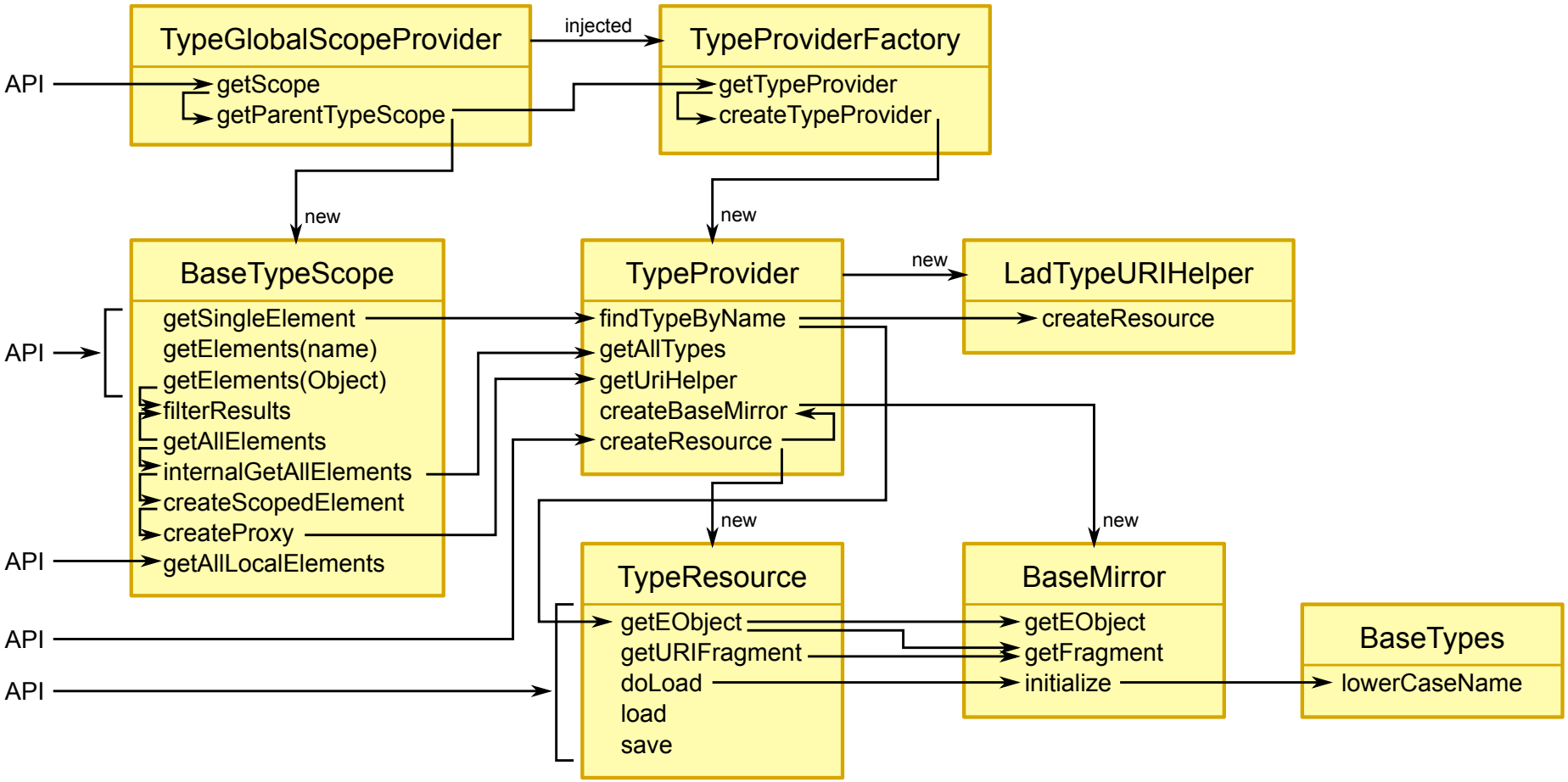

Types

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Type returns type::Type: UserType ;
UserType returns type::UserType: ClassType | RecordType ;

TypeReference returns type::TypeReference:
{type::TypeReference} reference = [type::NamedType | ID] ('.' remainder=TypeReference )? |
{type::ArrayType} reference = [type::NamedType | ID] ( '[' sizes += INT ']' )+ ;
```

Property Declaration

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PropertyDeclaration returns type::PropertyDeclaration:
    modifiers += Modifier type = TypeReference name = ID ;

FunctionDeclaration returns type::FunctionDeclaration:
    modifiers += Modifier type = TypeReference name = ID
    '(' (parameters += ParameterDeclaration (',' parameters += ParameterDeclaration)*)? ')'
    body = Body ;
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Base Types and Type Reference

```
/** Determine type of a literal: here a boolean value */
def dispatch Type getActualType(BooleanValue value) {
    return typeProvider.findTypeByName("boolean");
}

/** Recursive method to follow type references */
def dispatch Type getActualType(TypeReference ref) {
    return ref.remainder?.actualType?:ref.reference;
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- Use of Xtend signature-based dispatcher

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- Use of Xtend signature-based dispatcher
- Dispatch method returns type for boolean values
- Dispatch method resolves type reference

Declarations and Calls

```
/** Determine the type of a value, variable, or property declaration */
def dispatch Type getActualType(ValueDeclaration decl) {
    return decl?.typeReference?.actualType;
}

/** Determine the return type of a declared function */
def dispatch Type getActualType(FunctionDeclaration decl) {
    return decl.type.actualType;
}

/** Determines the type of a value, variable, or property reference */
def dispatch Type getActualType(ValueReference ref) {
    return ref?.reference?.actualType;
}

/** Determines the return type of a function call */
def dispatch Type getActualType(FunctionCall call) {
    return call.functionRef.actualType;
}
```

Meta-model for target language

- XML-schema to EMF converter[3]
- Existing meta-models e.g., JavaTypes [EEK+12]
- Standards or documentation e.g., IEC 61131-3 [IEC03]

[3] `http://yoxos.eclipsesource.com/places/node/org.eclipse.xsd.ecore.converter.feature.group`

Meta-model for target language

- XML-schema to EMF converter[3]
- Existing meta-models e.g., JavaTypes [EEK+12]
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Semantics of target language

- Type structures
- Expression and statement

[3] `http://yoxos.eclipsesource.com/places/node/org.eclipse.xsd.ecore.converter.feature.group`

Example runtime concepts

- Memory management
- Instantiation
- Garbage Collection
- Synchronization

Type and Expression Mapping

Example runtime concepts

- Memory management
- Instantiation
- Garbage Collection
- Synchronization

Example type mapping

- Source: Datatype **interval**
  - Arbitrary integer range
  - Wraps on overflow/underflow
- Target: Datatype **signed int32**
  - Range checks
  - Integration with operators, e.g., +, ++

Goal Improve DSLs development and maintenance

Summary

Goal Improve DSLs development and maintenance

Methods

- Base type integration in Xtext
- Meta-models for type systems
- Grammar composition
- Transformation recipes

DSL design patterns

- Public accessible collection
- Discuss further typing concepts, e.g., let, generics
- Better language composition

Type systems and type transformation

- Integration of XSemantics
- Concept evaluation of DSL for type transformation

References I

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