54. How to Synchronize Models with Triple Graph Grammars for Data Connection

Prof. Dr. U. Aßmann
Technische Universität Dresden
Institut für Software- und Multimediatechnik
Gruppe Softwaretechnologie
http://st.inf.tu-dresden.de
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1) Triple Graph Grammars
2) Specifying TGG in MOFLON
3) Using TGG in MOFLON
4) The Tornado mapping method

Literature

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Literature

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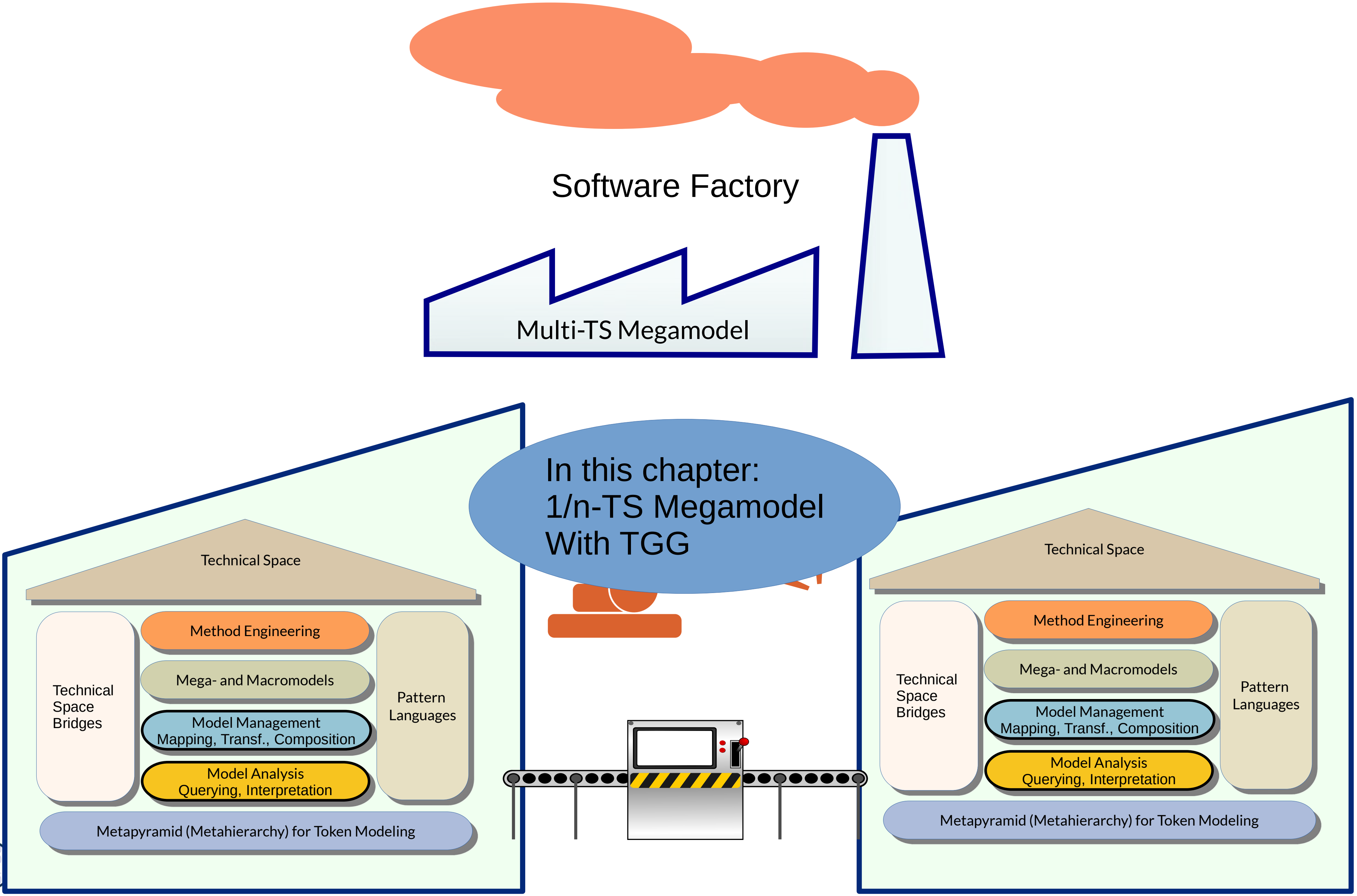
Q13: A Software Factory's Heart: the Multi-TS Megamodel



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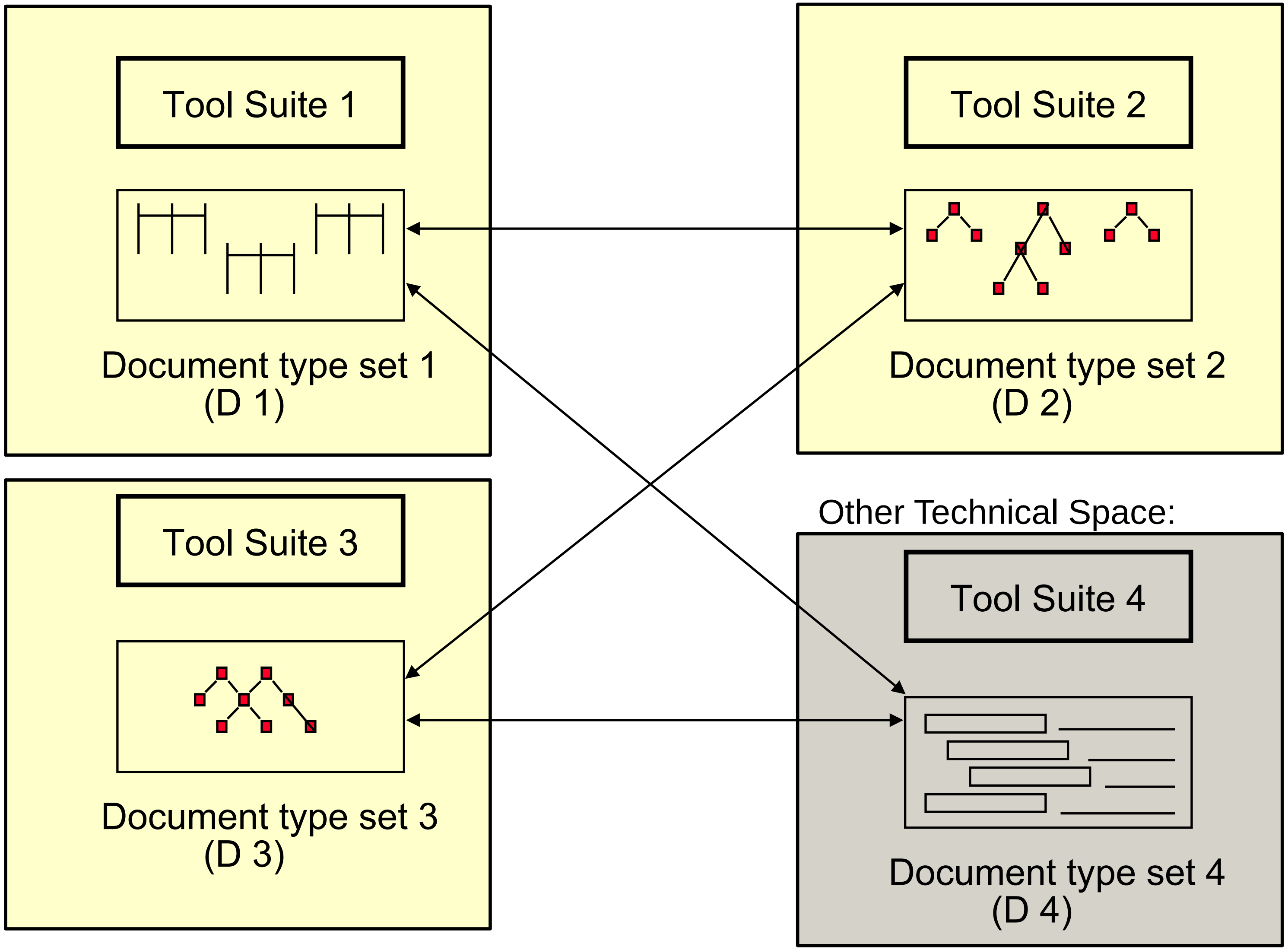
Integration of Tool Suites by Data Connection

[ES89, 6, S. 11]

- Material of several tool (suites) can be ***data-connected*** by transformations or access adaptations



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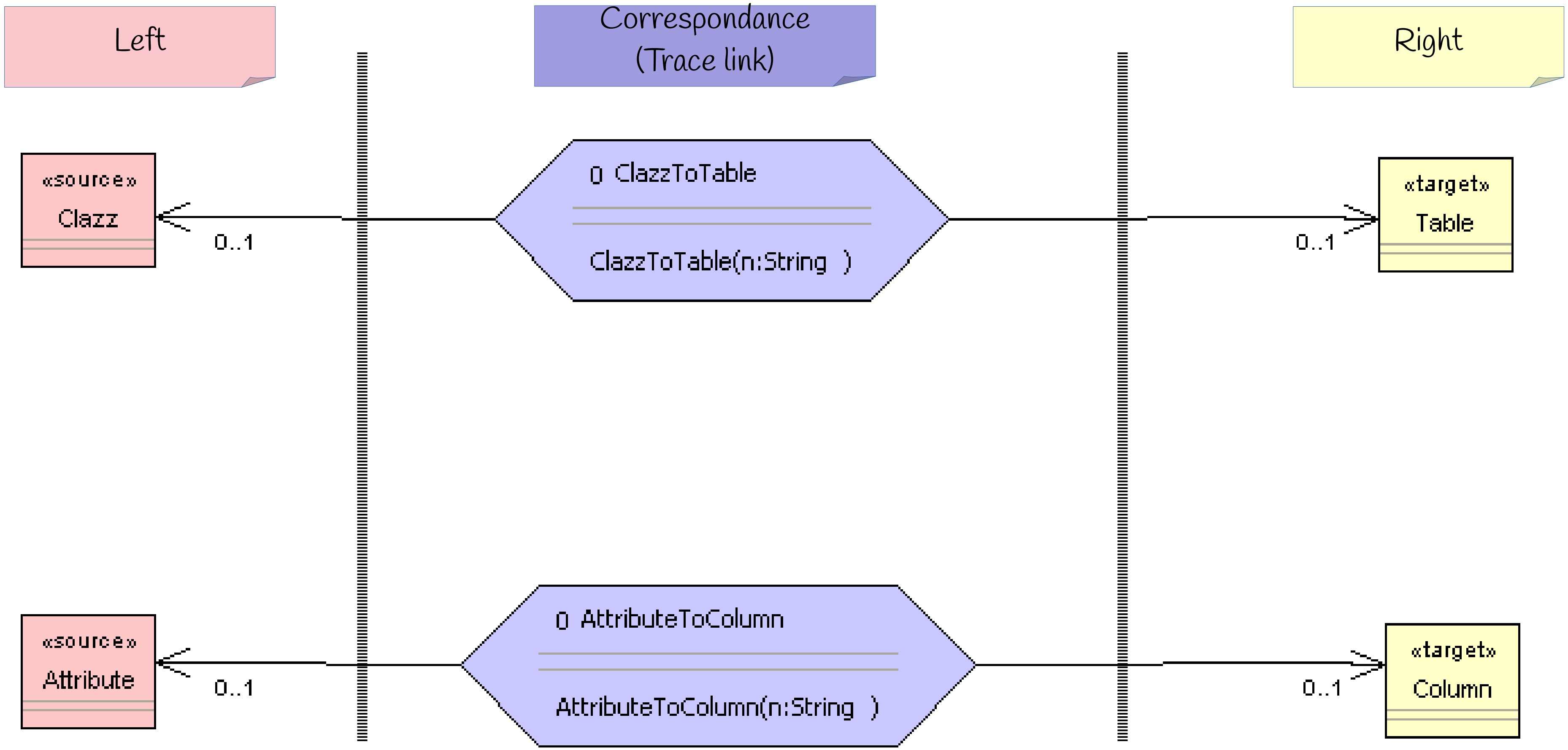
54.1 „Synchronizing“ Models with Triple Graph Grammars

- Mapping graphs to other graphs, also in data connections of different tools
- Specification of mappings with mapping rules
- Incremental transformation
- Traceability

Triple Graph Grammars – Moflon Example

- A **Triple Graph Grammar (TGG)** is a mapping-oriented transformation system, consisting of rules with three „areas“ (better called **metamodel mapping grammars**)
  - Left side: (source) graph pattern 1 in (source) graph 1
  - Right side: (target) graph pattern 2 in (target) graph 2
  - **Middle: relational expression (net)** relating graph pattern 1 and 2 (trace model)



Basic Types of Synchronization Rules

Depending on the modification colors, a TGG rule can be checking or creating the correspondance.

Rule classes from [KS05] Koenigs/Schuerr 2005:

- **Consistency Checking rules** – test whether both patterns exist
  - modification color is black (test)
- **Traceability relationship creating rule** – add a trace relation between elements of both sides
  - modification color is green in correspondance part (add)
- **Create model element** in one domain matching its correspondant
  - modification color is green on one side (add)
- **Lower layer create model element** – create model in a lower grammar layer
  - modification color is green on lower layer (add)

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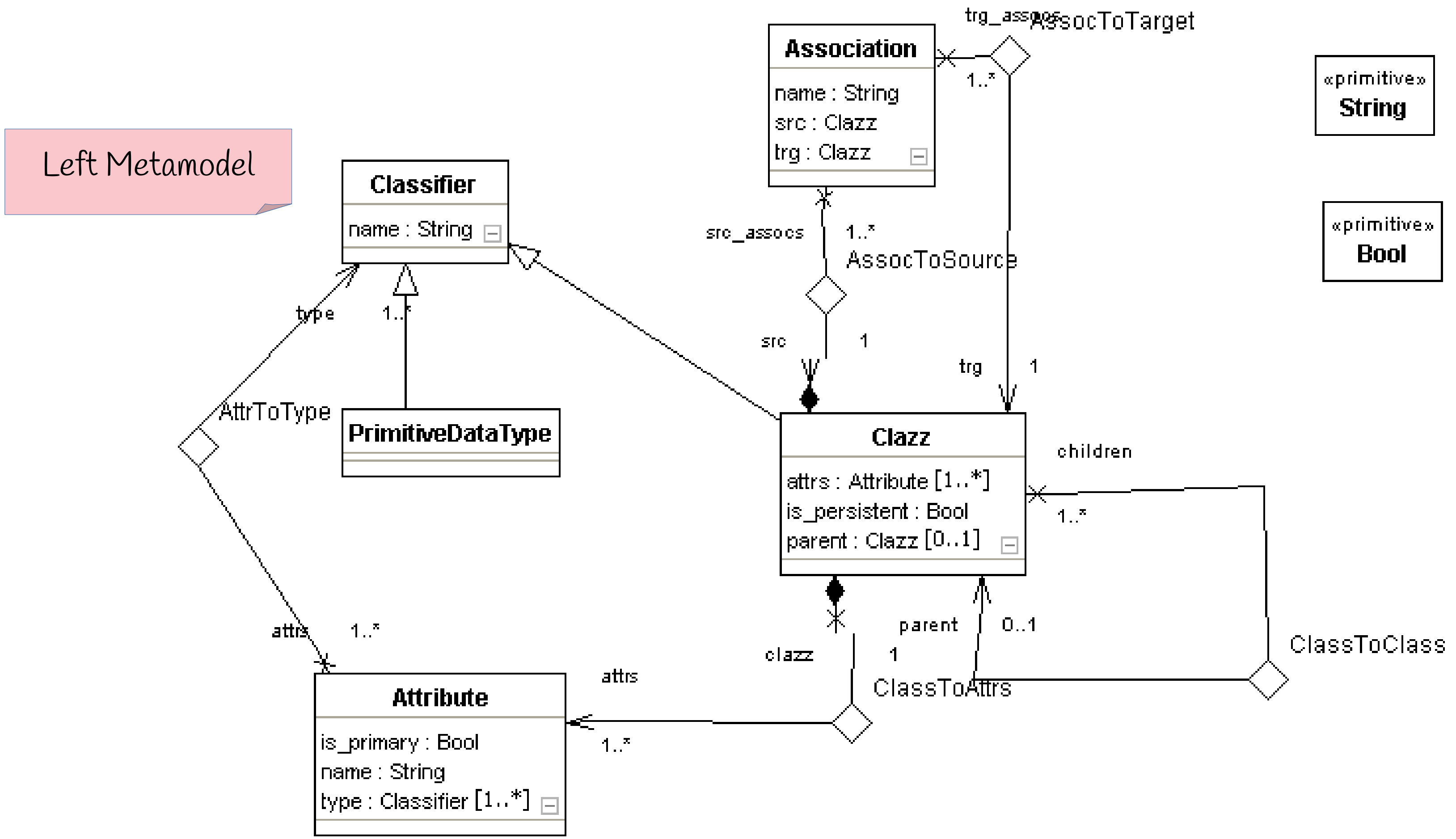
54.2.1. Mapping Objects to Tables (Object-Relational Mapping, ORM)

TGG for Object–Relational Mapping (ORM)
Left Metamodel: Class Diagram Metamodel (CD)

- Synchronize Class-Diagram-metamodel (CD) with a relational schema (RS): object-relational mapping (ORM)



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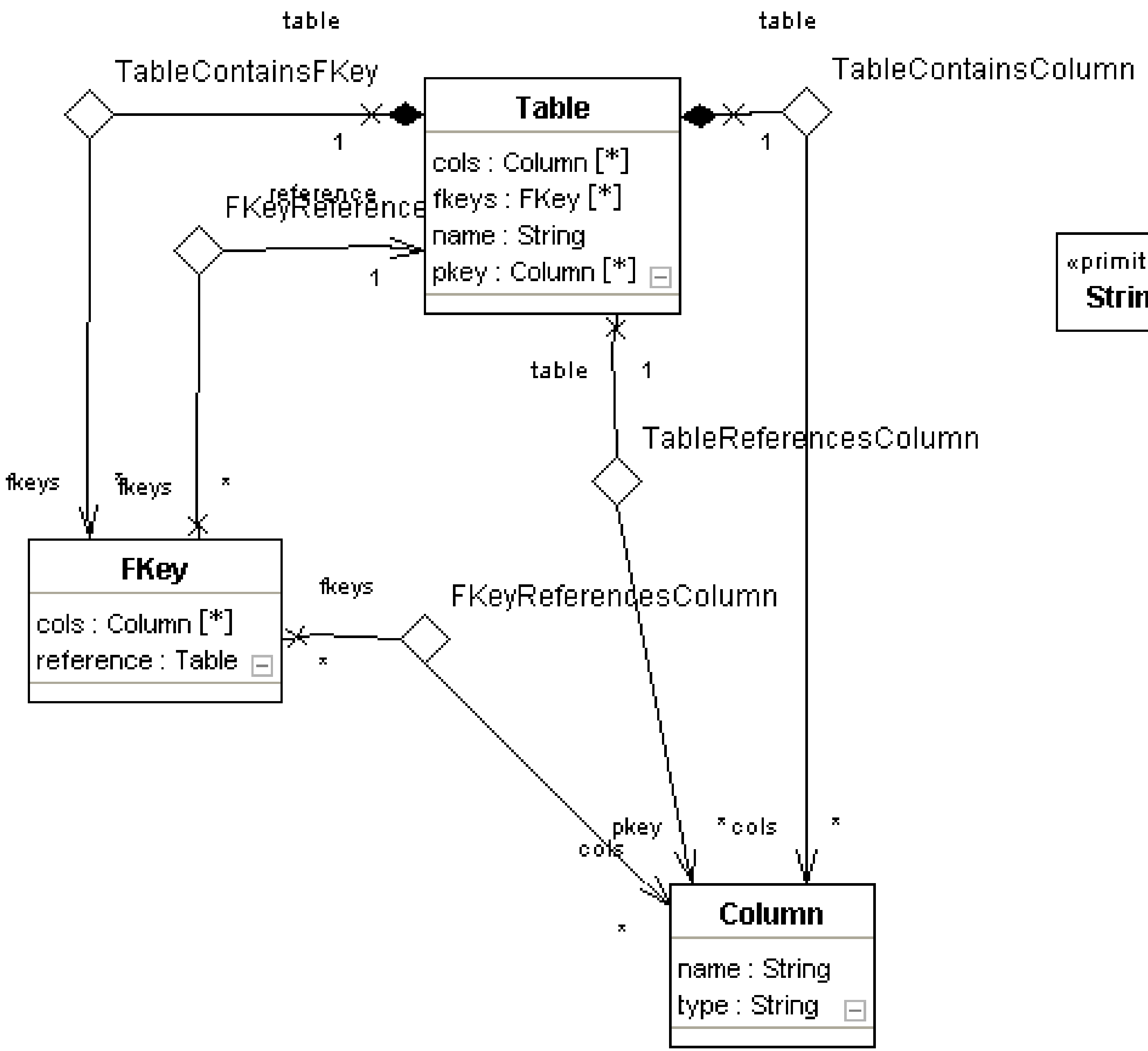
Right Metamodel:
Relational Metamodel (DB, relational schema)

Right Metamodel



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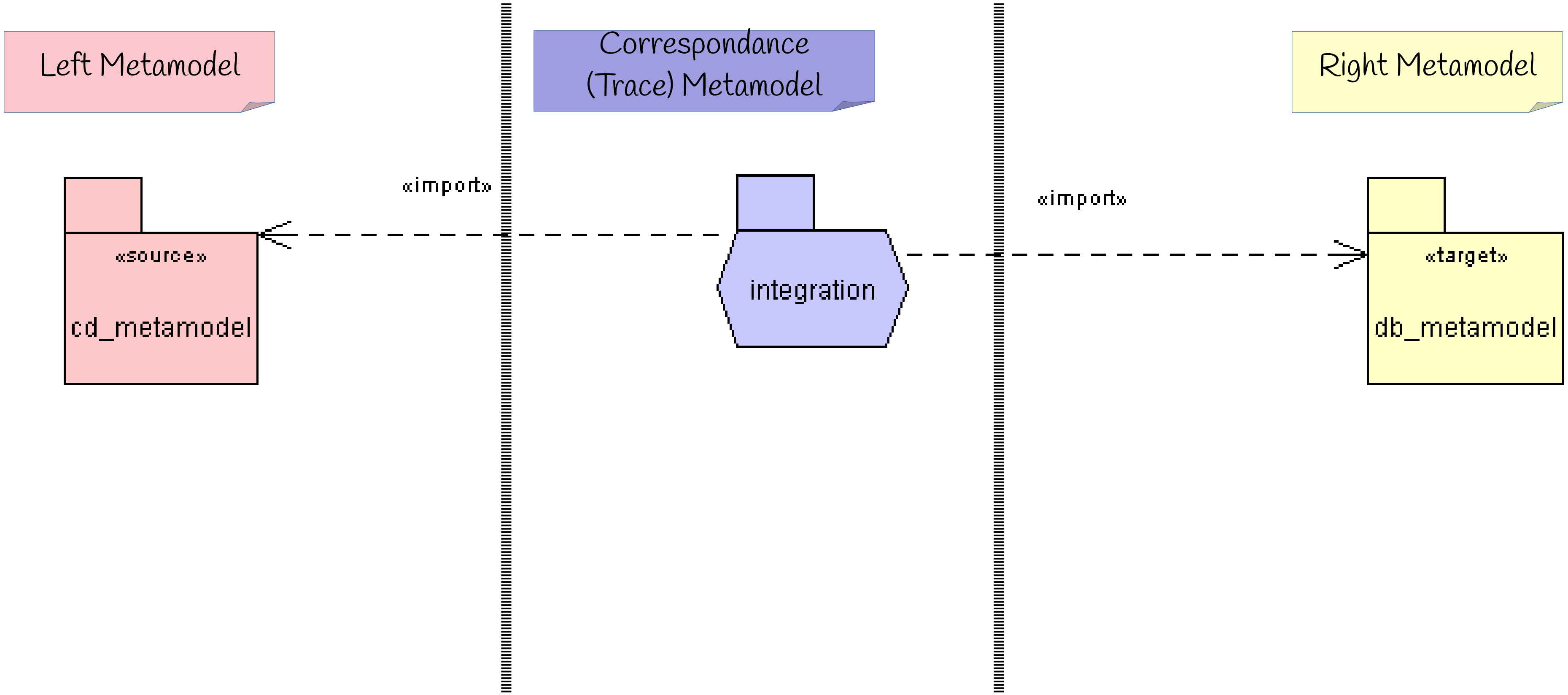
TGG for Object–Relational Mapping (ORM)

- The metamodel mapping grammar of a TGG has a top rule (start rule) which describes the relationship of the graphs on topmost level



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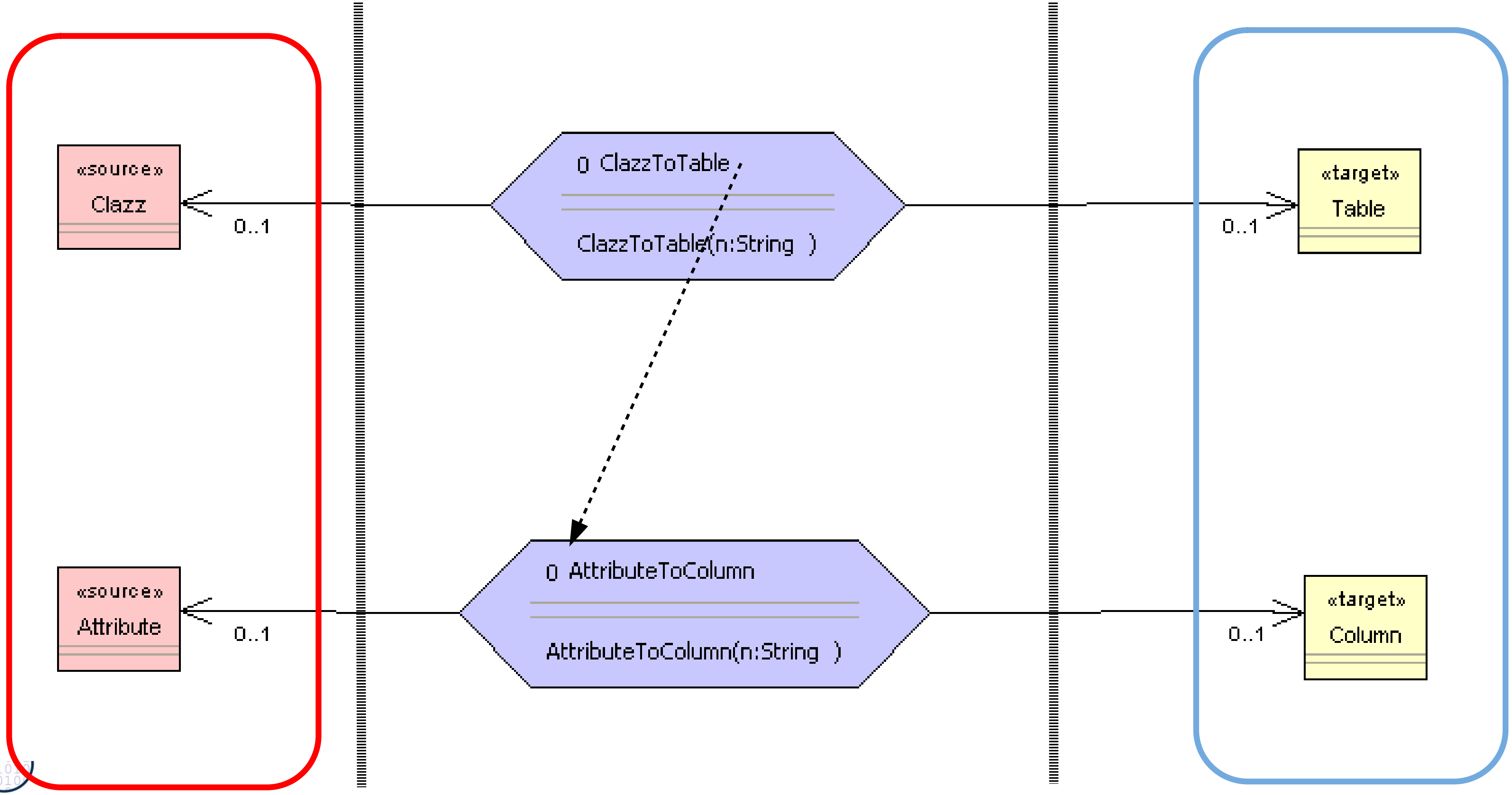
Example of Consistency-Checking Rule

- From the top-rule `ClazzToTable`, other TGG rules are associated („called"/"invoked")
- In this case, the TGG only checks (black color – TEST)
- Q: What happens, if both sides are in different Technical Spaces?



TGG Specify Transformation Bridges Between Roles and Technical Spaces

- TGG can also be used to data-exchange and synchronize Material classes and roles
  - between two material objects
  - between two tools with different repositories
    - even in different technical spaces
- The only assumption: 1:1 mappings of model elements

TGG are a fine technique to build *transformation bridges for data connection* between tools, even in different technical spaces.

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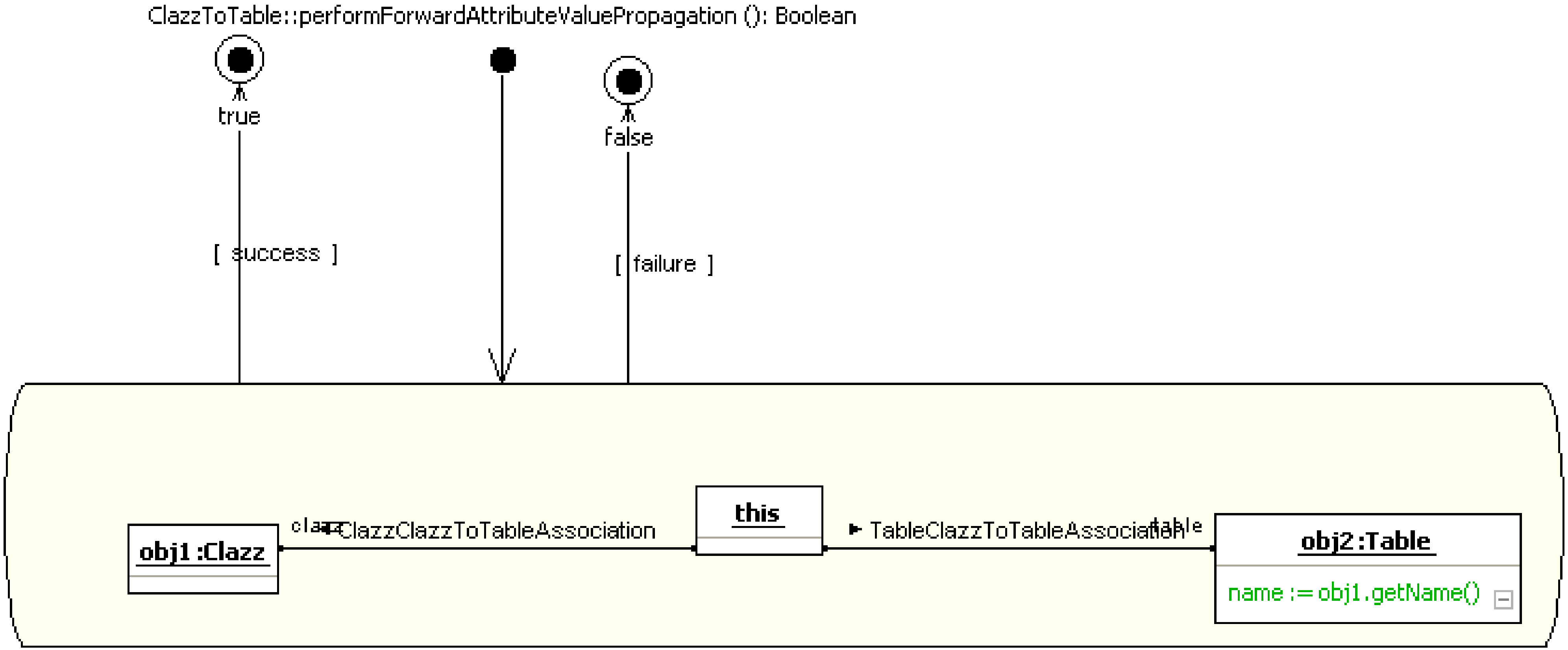
54.2. Triple Graph Grammars in MOFLON

- MOFLON in MOF Technical Space
- eMOFLON in EMOF TS

- Because they are named, TGG rules can be started by Fujaba Storyboards (activity diagrams)
- The activites can be associated to a transformation class ClazzToTable



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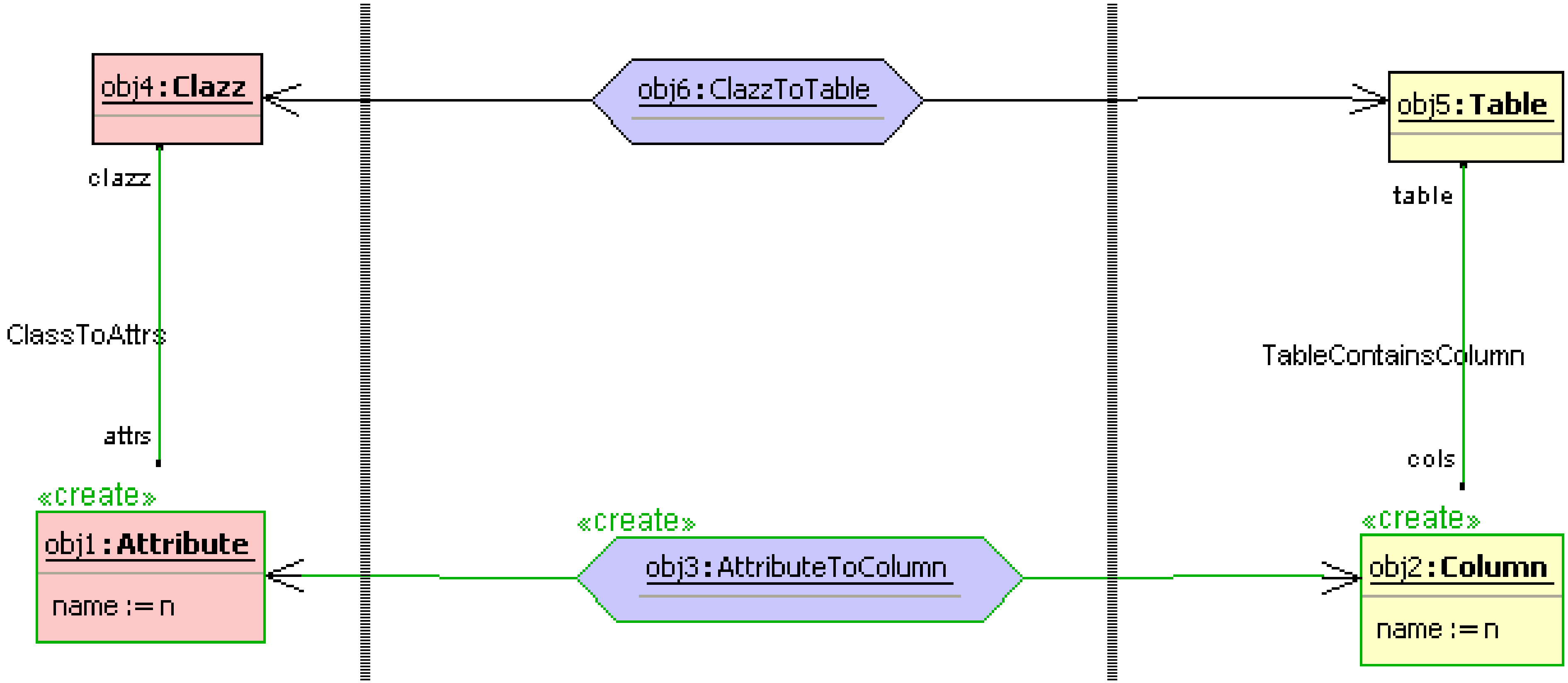
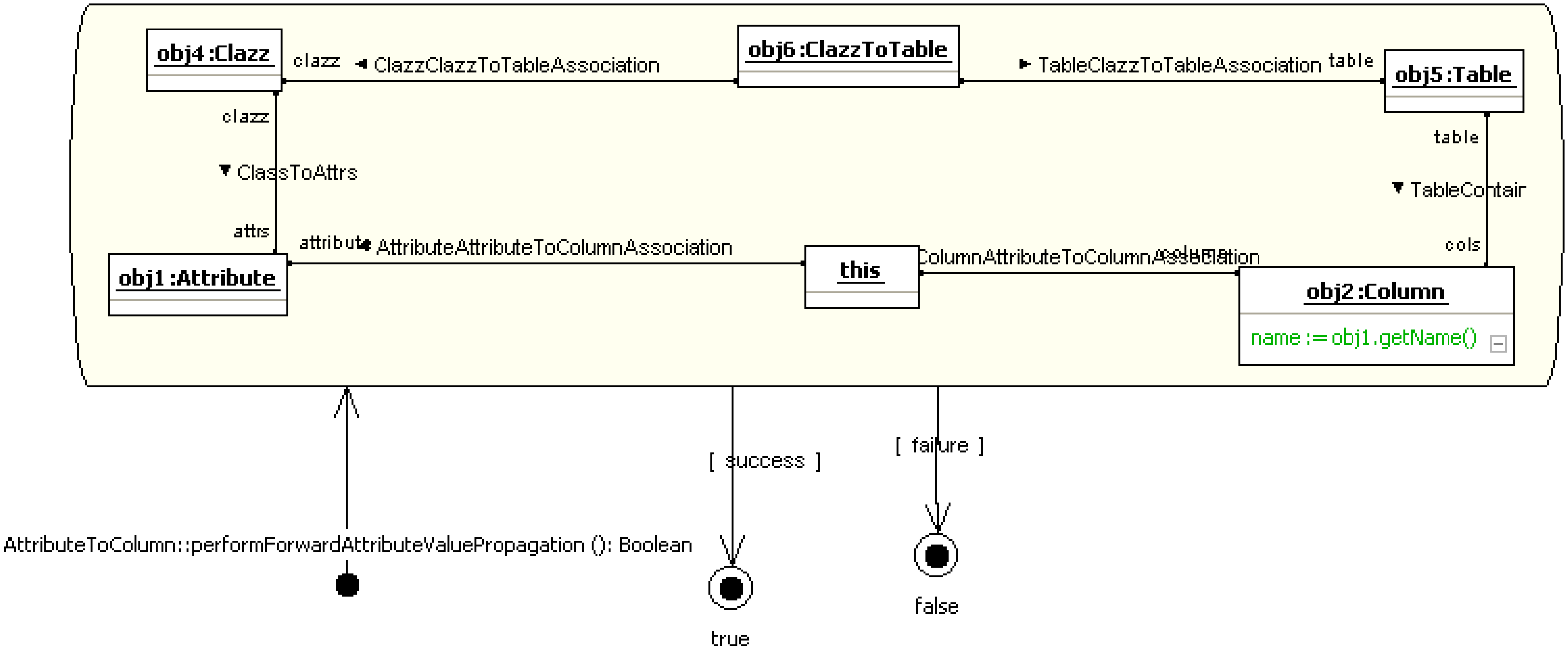
Example of Lower-Level-Creation Rule

- *Lower-level-creation rule* creates lower level elements and a pairwise correspondance of model elements on both sides
  - Here, objects on the lower level are created anew if needed from the tested upper level



Triple Graph Grammars – Moflon Example

- Notation in Moflon/Fujaba Storyboards
- Checking a pattern with adding an attribute to obj2



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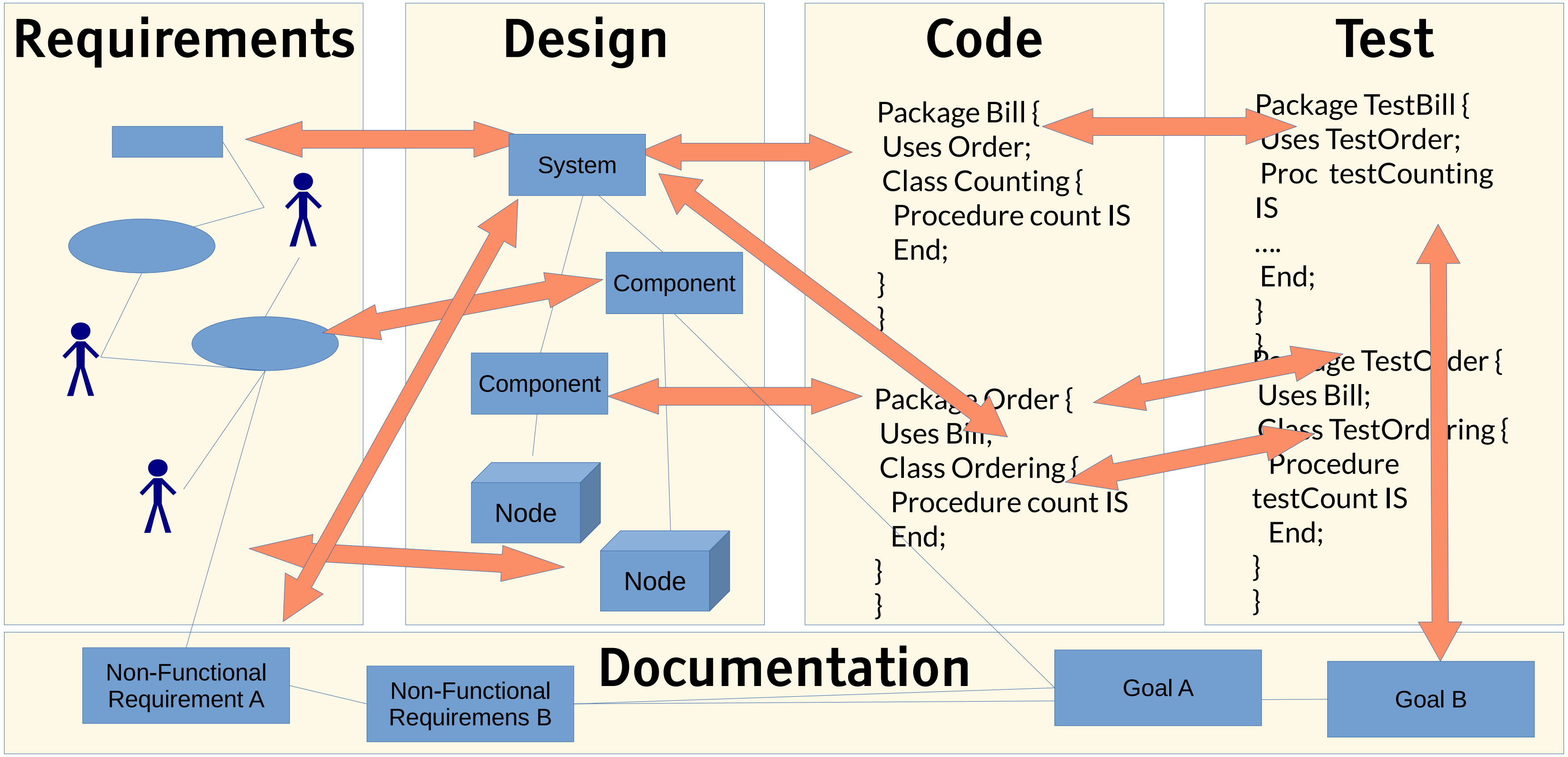
Q12: The ReDoDeCT Problem and its Macromodel

- The **ReDoDeCT problem** is the problem how requirements, documentation, design, code, and tests are related (→ V model)
- Mappings between the Requirements model, Documentation files, Design model, Code, Test cases
- A **ReDoDeCT macromodel** has maintained mappings between all 5 models



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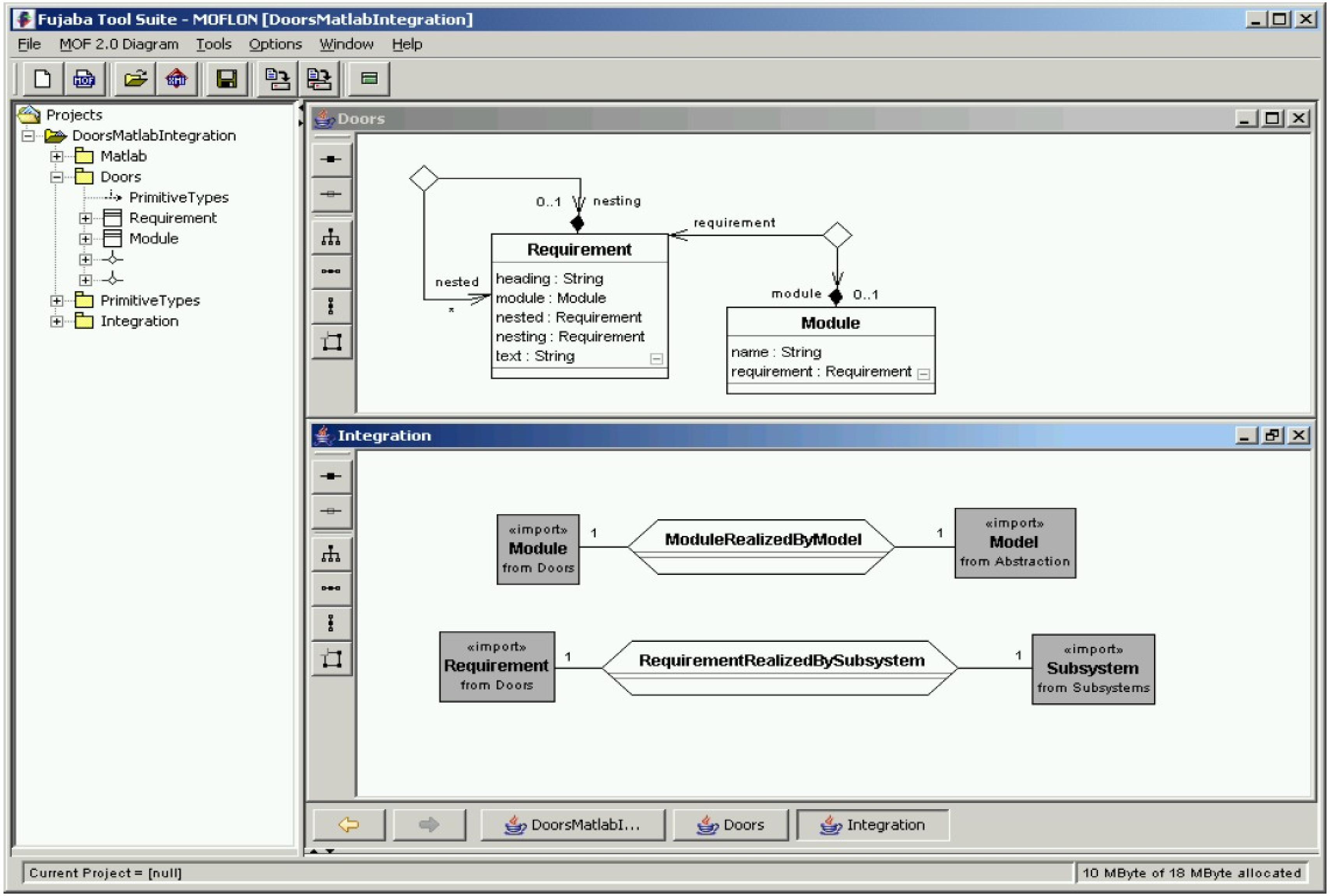
Ex. 2: TGG Coupling of Requirements Specification and Design



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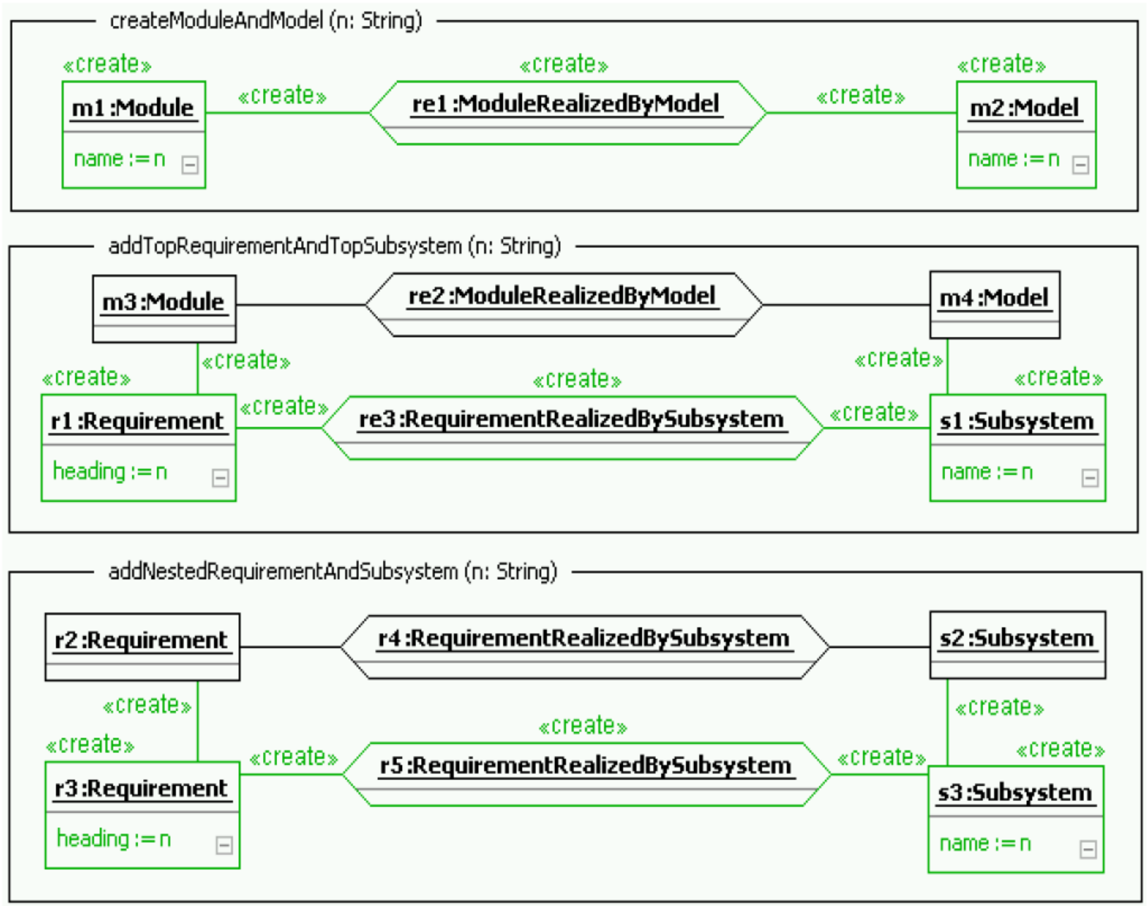
TGG Coupling Requirements Specification and Design

- This TGG grammar builds up a module-requirements graph
- Starting from a relation “ModuleRealizedByModel” and “RequirementRealizedBySubsystem”



initial, creational

lower-layer creational

lower-layer creational

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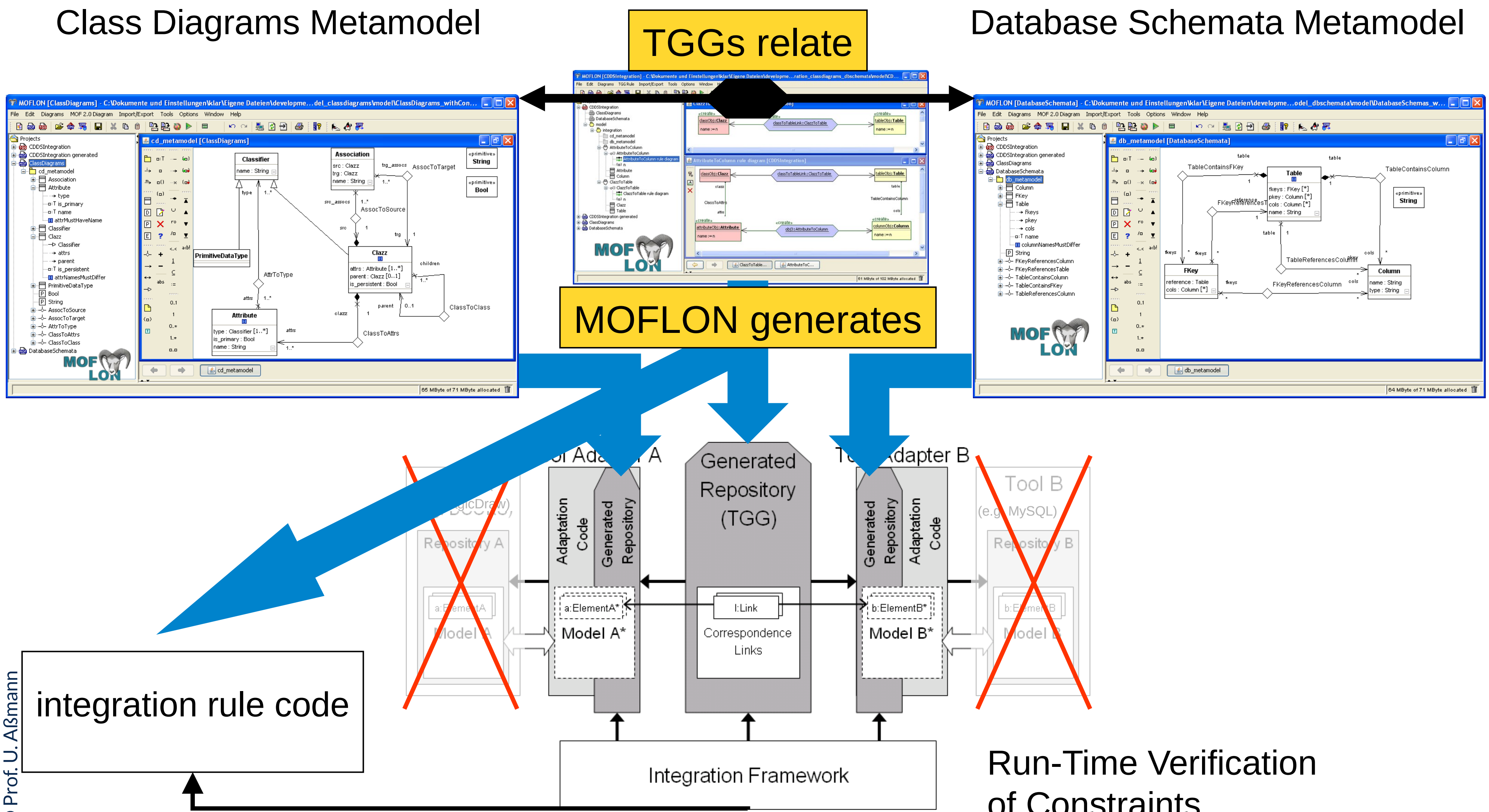
54.3. Using Triple Graph Grammars in MOFLON

Example: Object-Relational Mapping "TiE-CD-DB": (ClassDiagrams / DatabaseSchema)



Run-Time Verification of Constraints

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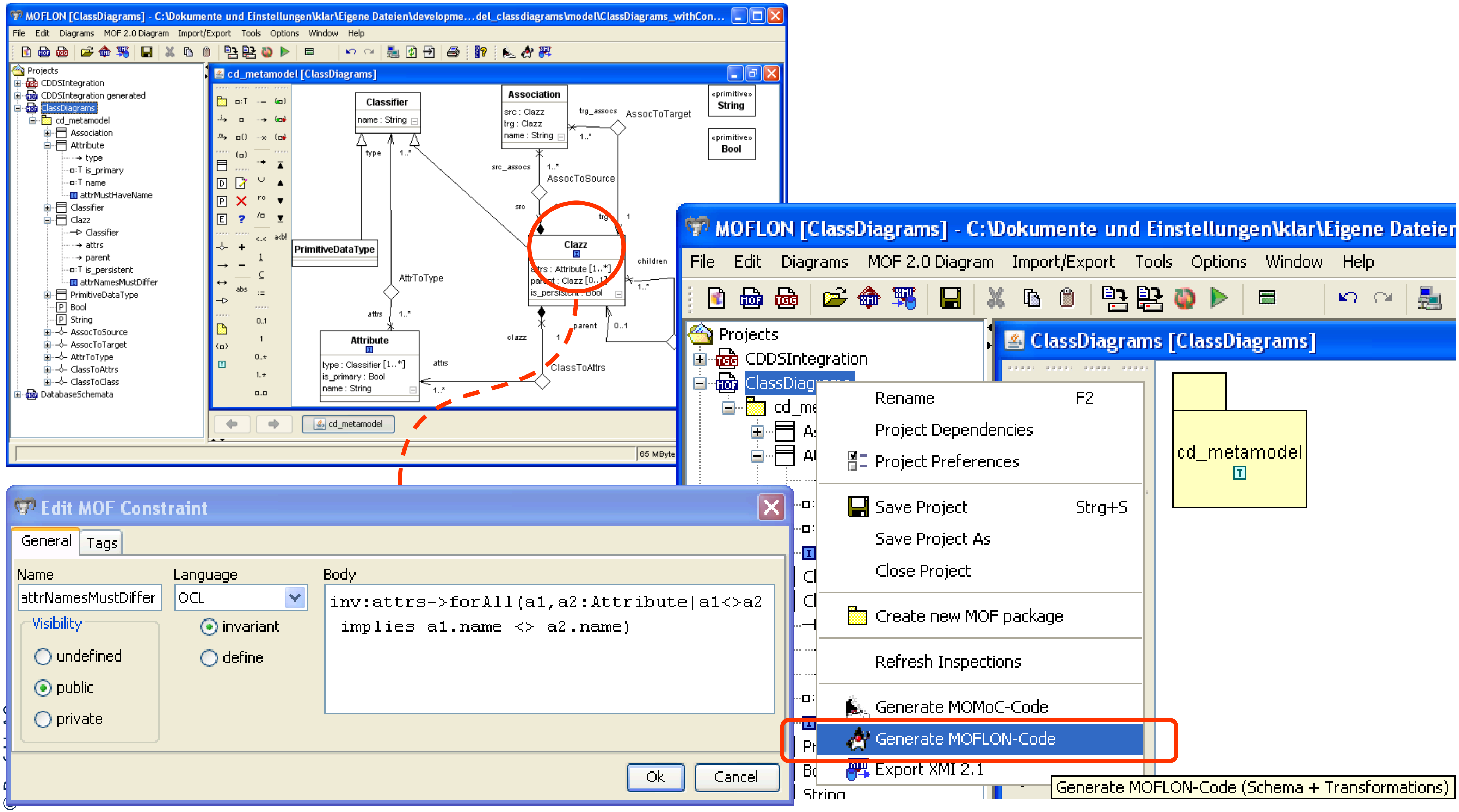
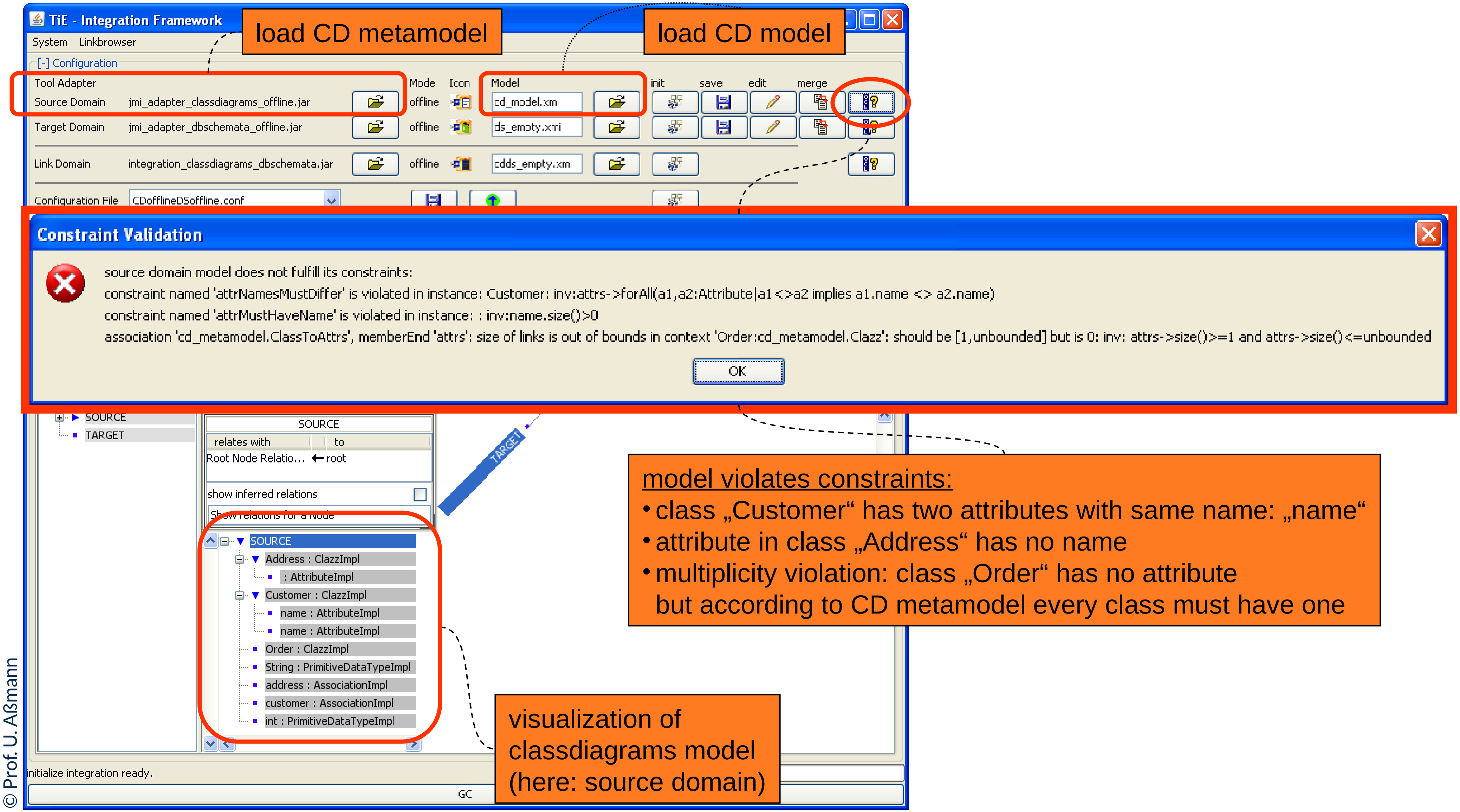
TiE-CD-DB – Constraints in Class Diagrams (1) Generate Code from MOF model (CD metamodel)



TiE-CD-DB – Constraints in Class Diagrams (2)
Loading Metamodels and Models



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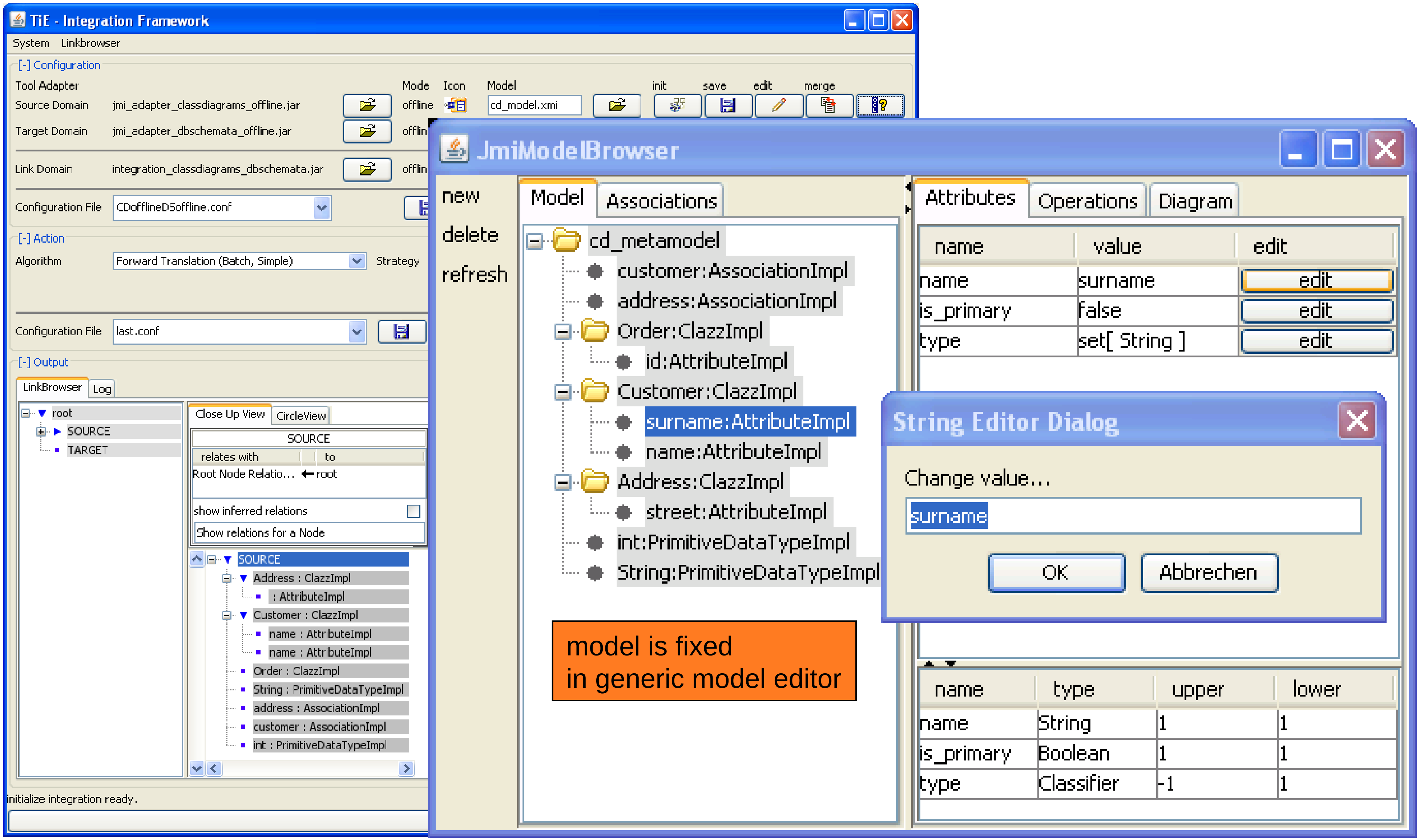
TiE-CD-DB – Constraints in Class Diagrams (3) Model Browser



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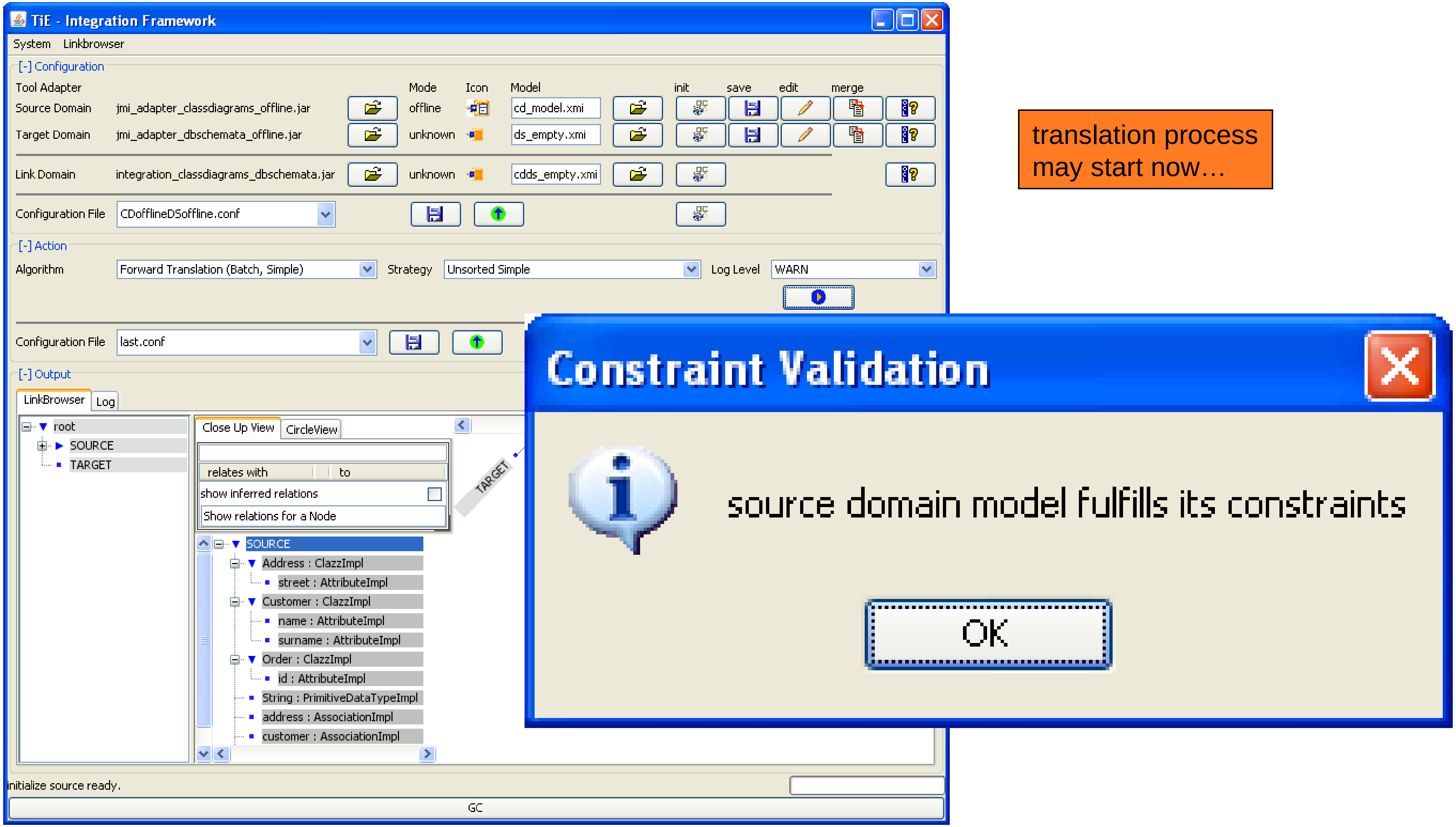
TiE-CD-DB – Constraints in Class Diagrams (4) Integration Framework



translation process may start now…

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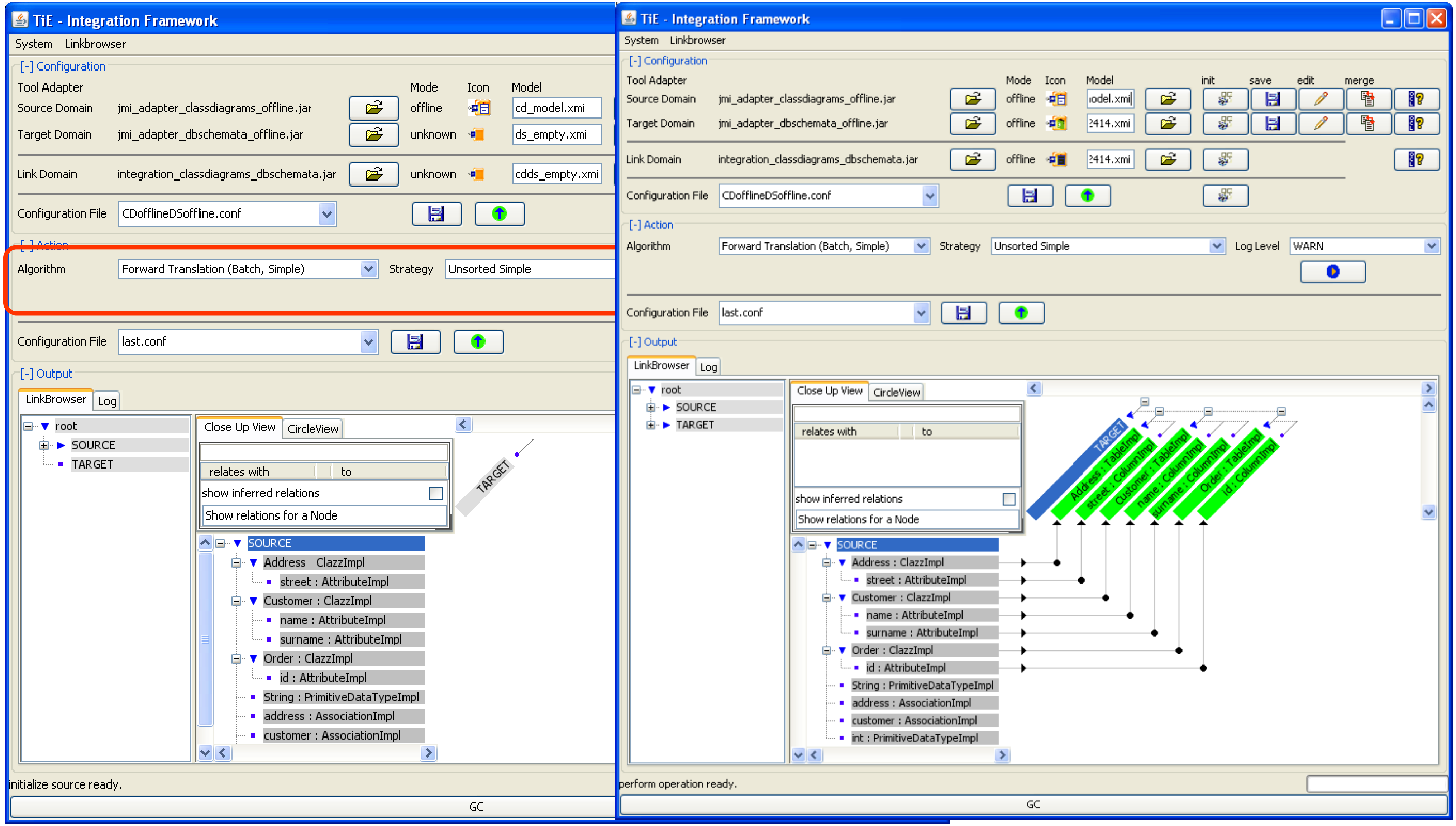
TiE-CD-DB – Constraints in Class Diagrams (5) Forward Translation to DB representation



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Other Software Engineering Applications of Model Synchronization

- Mapping a PIM to a PSM in Model-Driven Architecture
- Graph Structurings (see course ST-II)
- Refactorings (see Course DPF)
- Semantic refinements
- Round-Trip Engineering (RTE)

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54.4 The Tornado Method: Specification of TGG Rules using Textual Concrete Syntax

- Slides about Tornado courtesy to Mirko Seifert and Christian Werner
- Presented at Fujaba Days 2009, Eindhoven, The Netherlands, 16.11.2009
- Christian Werner. Konzeption und Implementierung eines Debuggers für textuelle Triple Graph Grammar Regeln. Belegarbeit, Lehrstuhl Softwaretechnologie, 2010, TU Dresden
- available on request

Motivation for Textual Syntax of TGG

- TGGs are fine for model synchronization, but writing TGG rules is not always easy

  Why?

- Rule specification typically on the level of abstract syntax
  - Complex abstract syntax (AS) graphs vs. simple concrete syntax (CS) fragments
  - Rule designers not always familiar with AS
- Rule specification is based on graphical syntax
  - But: There is lots of textual (modelling) languages
  - Gap: Graphical rules vs. textual models
  - Large graphical rules are hard to read

Can we do better?

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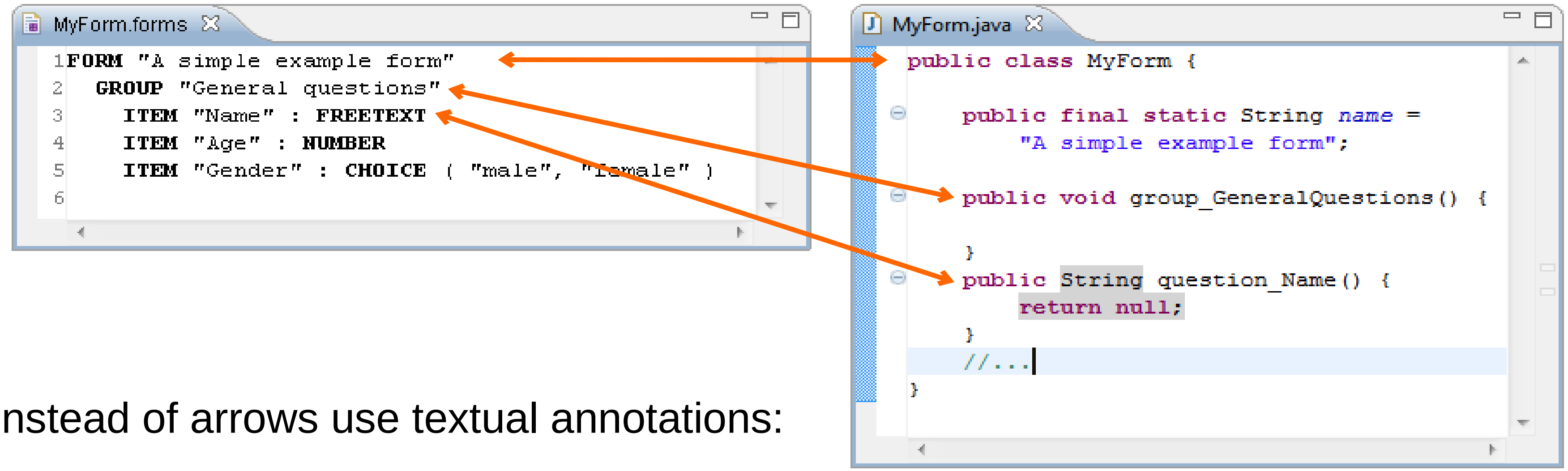
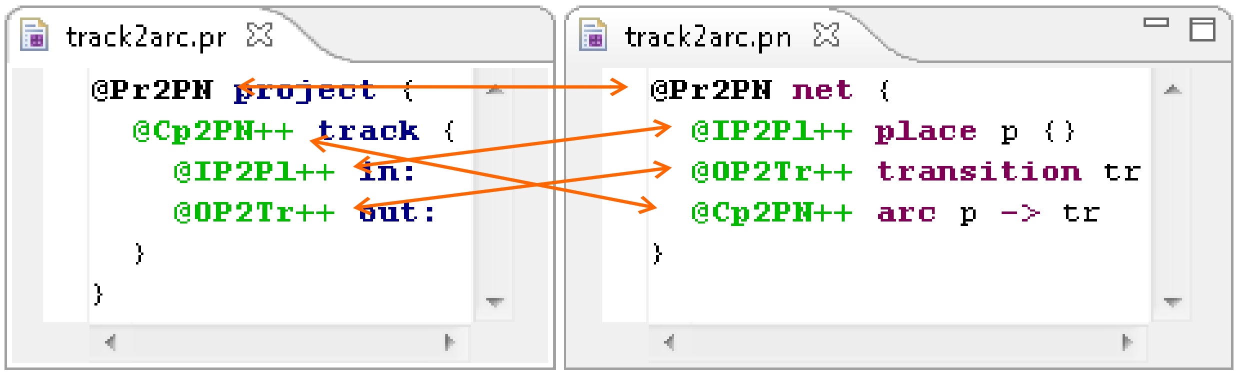
Idea for Rule Specification in EMFText

- employ EMFText; use concrete textual syntax of involved languages
- derive rules from pairs of models
- do it in a generic way (automatic application to any language)



Instead of arrows use textual annotations:



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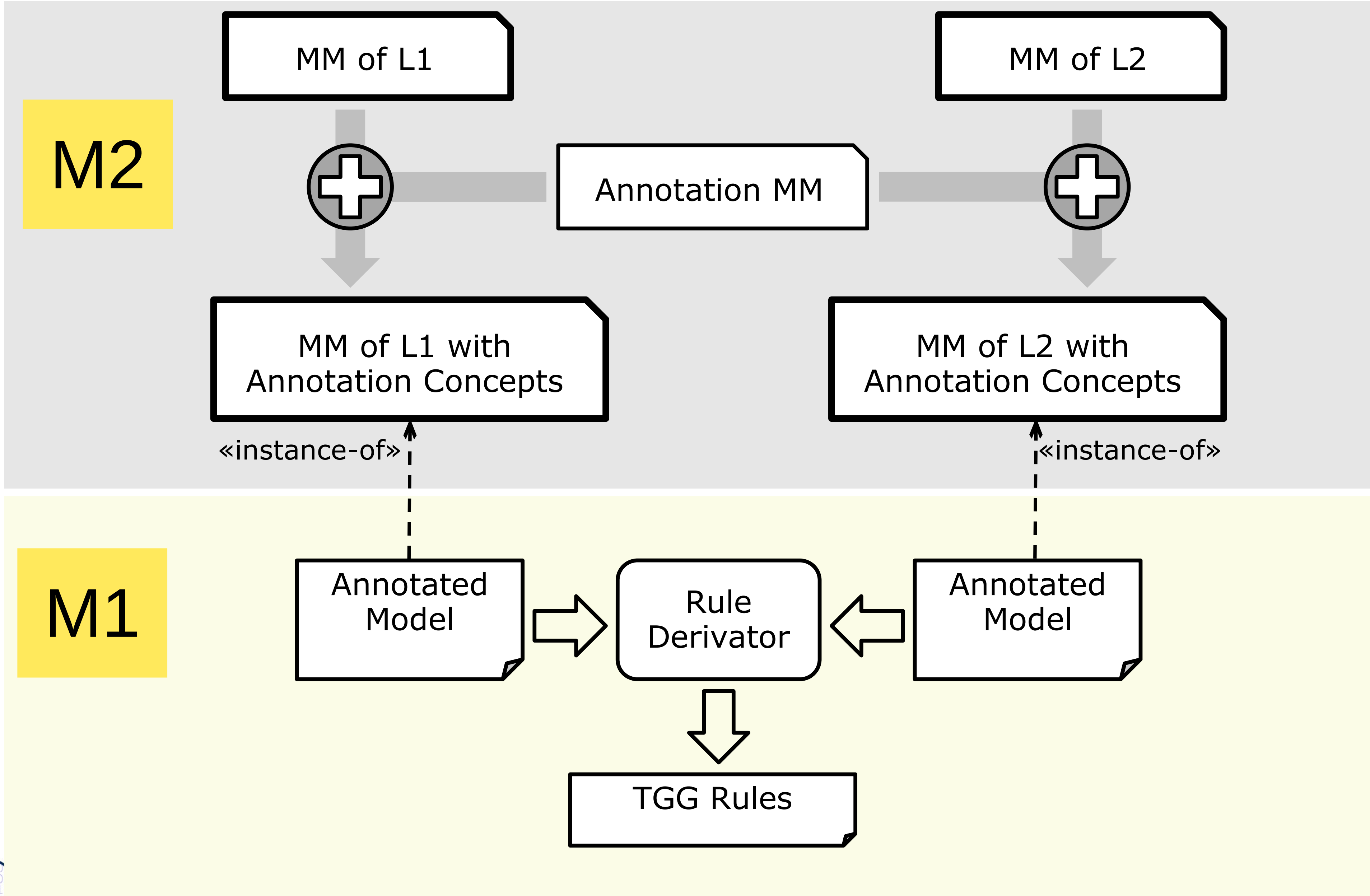
Tornado Generation Process of TGG Rules



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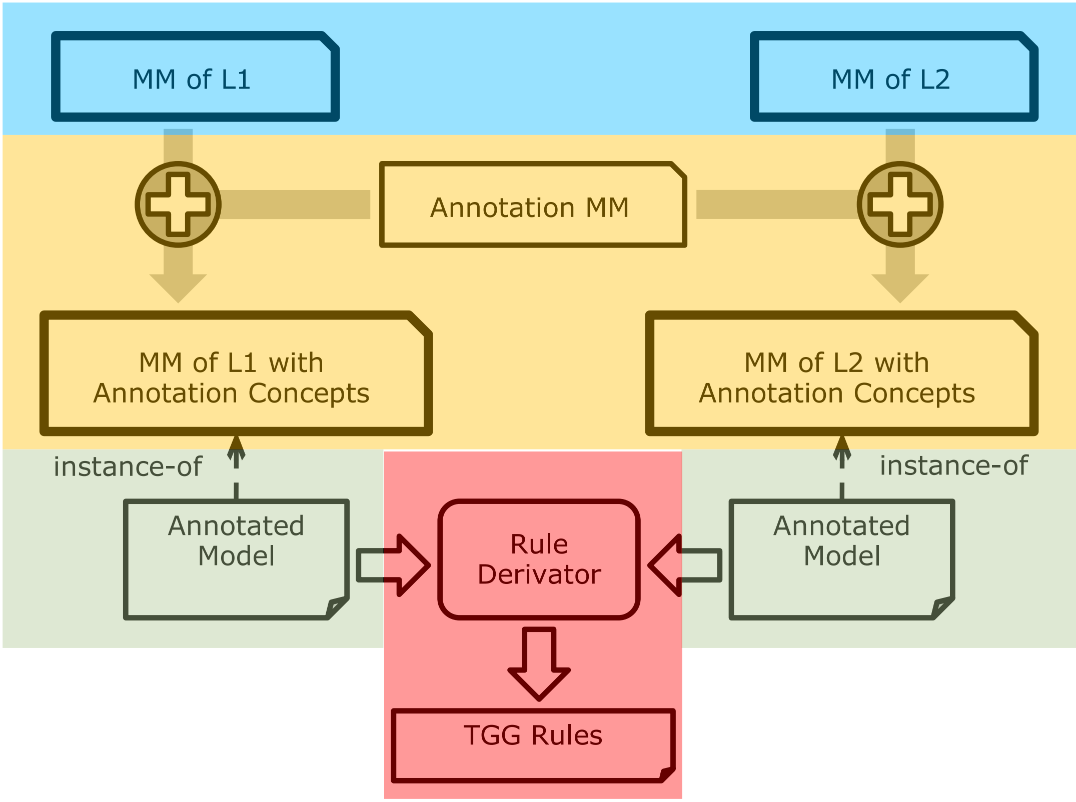
Generation Steps of Tornado Method

1. Make meta models extensible

2. Extend meta models
   (with annotation concepts)

3. Extend concrete syntax

4. Derive rules from
   model pairs



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Step 1 – Getting (more) Extensible Metamodels

Extensibility provided by Ecore (EMOF):

- Add new metaclasses (i.e., new complex types)
- Reference existing metaclasses (Reuse)
- Subclass existing metaclasses

What is missing in EMOF:

- Distinction between subtyping and inheritance
- Extensibility for primitive types
- Example:
  - Can't add things that do not have a property year
  - Can't add subtypes for EString

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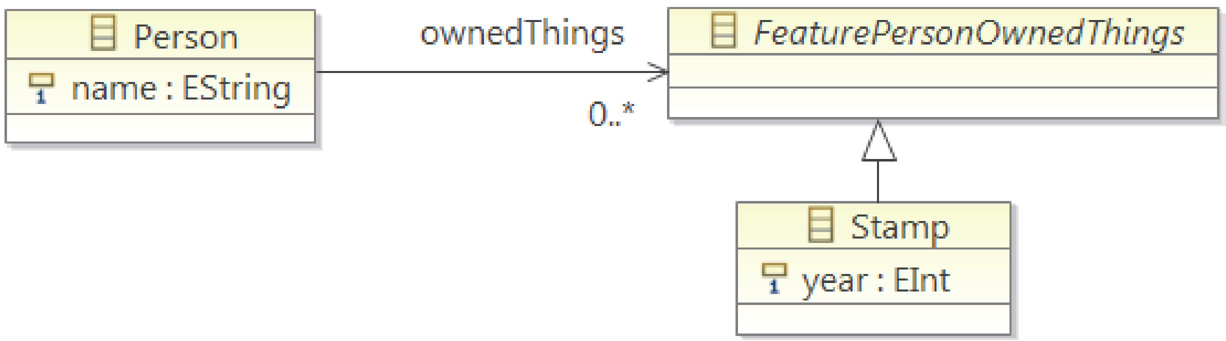
Step 1a – Getting Extensible Metamodels

Separate subtyping and inheritance (algorithm from [HJSWB]):

For each feature's type that has at least one superclass or defines at least one feature:

- Introduce a new abstract metaclass Feature<ClassName><FeatureName>
- Change the type of the feature to the new metaclass
- Make the former type of the feature a subclass of the new metaclass

Example:



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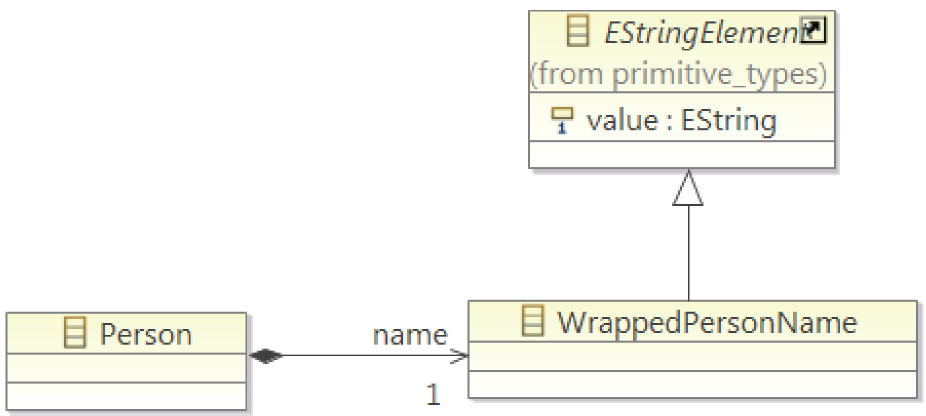
Step 1b – Getting Extensible Metamodels

Wrap primitive types (also from [HJSWB]):

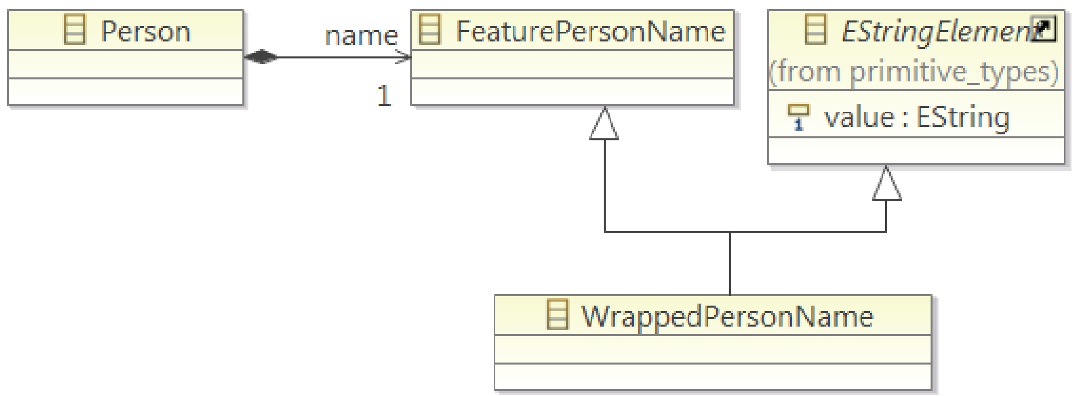
For each attribute that has a primitive type:

- Create a new subclass of the primitive type wrapper class
- Replace attribute with reference to new subclass

Example:



Wrapped attribute



Wrapped attribute after step 1a)

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Step 2 – Extending Metamodels with Annotation Concepts

Goal:

- Every model element can be annotated

HowTo:

- For each meta class X create new metaclass AnnotableX with
    - Reference to class Annotation
      (to store the annotation)
    - Reference to the original class X
      (to store the data of X)
    - Make AnnotableX a subclass of each feature class that X inherits from
      (to make AnnotableX usable wherever X can be used)

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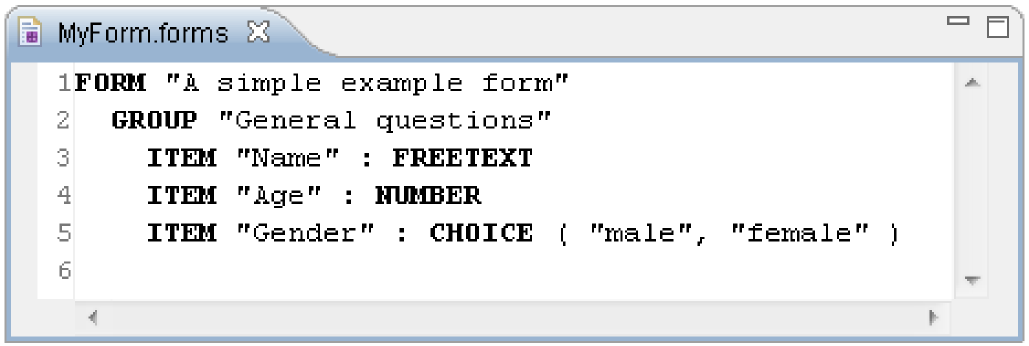
Step 3 – Extending the Concrete Syntax Specification

- Steps 1 and 2 added annotations concepts on the level of abstract syntax, but concrete one is need to write them down
- Textual syntax tools (e.g., EMFText, xText and TCS) use one rule per metaclass
  - Retain the existing syntax rules
  - Add syntax rules for new annotation classes in meta model

```
Form           ::= "FORM" name['"','"'] groups*;
AnnotableForm ::= (identifier[IDENT])+ (type[TYPE])? form;
```

```
@1  !    FORM "A simple example form"
```

```
IDENT is some identifer starting
      with an @
TYPE  is !, ++ or --
```



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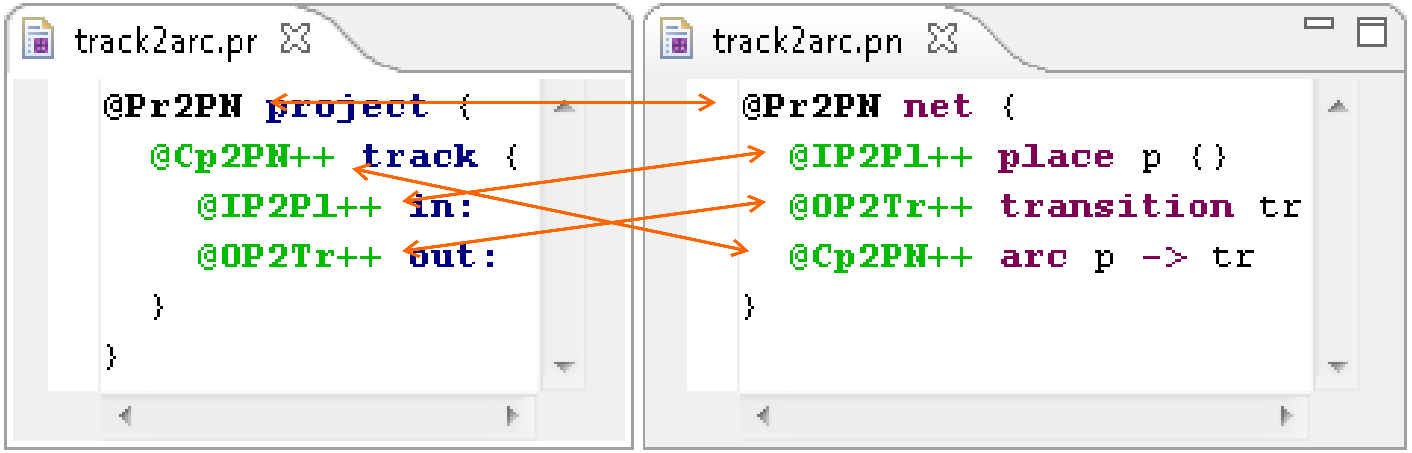
Step 3 – Extended Concrete Syntax

Rail tracks to Petrinet example



(bold black and green elements are new – TGG rule annotations)

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Step 4 – Deriving Rules from Model Pairs

- For each annotated model element, create a rule node
- For each set of model elements that are annotated with the same identifier,
  - create a correspondence node and create links connecting the new correspondence node with the respective rule nodes
- Mark all rule nodes as "create" where the corresponding model element is annotated as create element
- For each pair of model elements that is connected by exactly one reference
  - create a link between the respective rule nodes
- For each pair of model elements that is connected by multiple references
  - use the references specified in the annotation
  - and create links between the respective rule nodes

track2arc.pr

```
@Pr2PN project {
  @Cp2PN++ track {
    @IP2Pl++ in:
    @OP2Tr++ out:
  }
}
```

track2arc.pn

```
@Pr2PN net {
  @IP2Pl++ place p {}
  @OP2Tr++ transition tr
  @Cp2PN++ arc p -> tr
}
```

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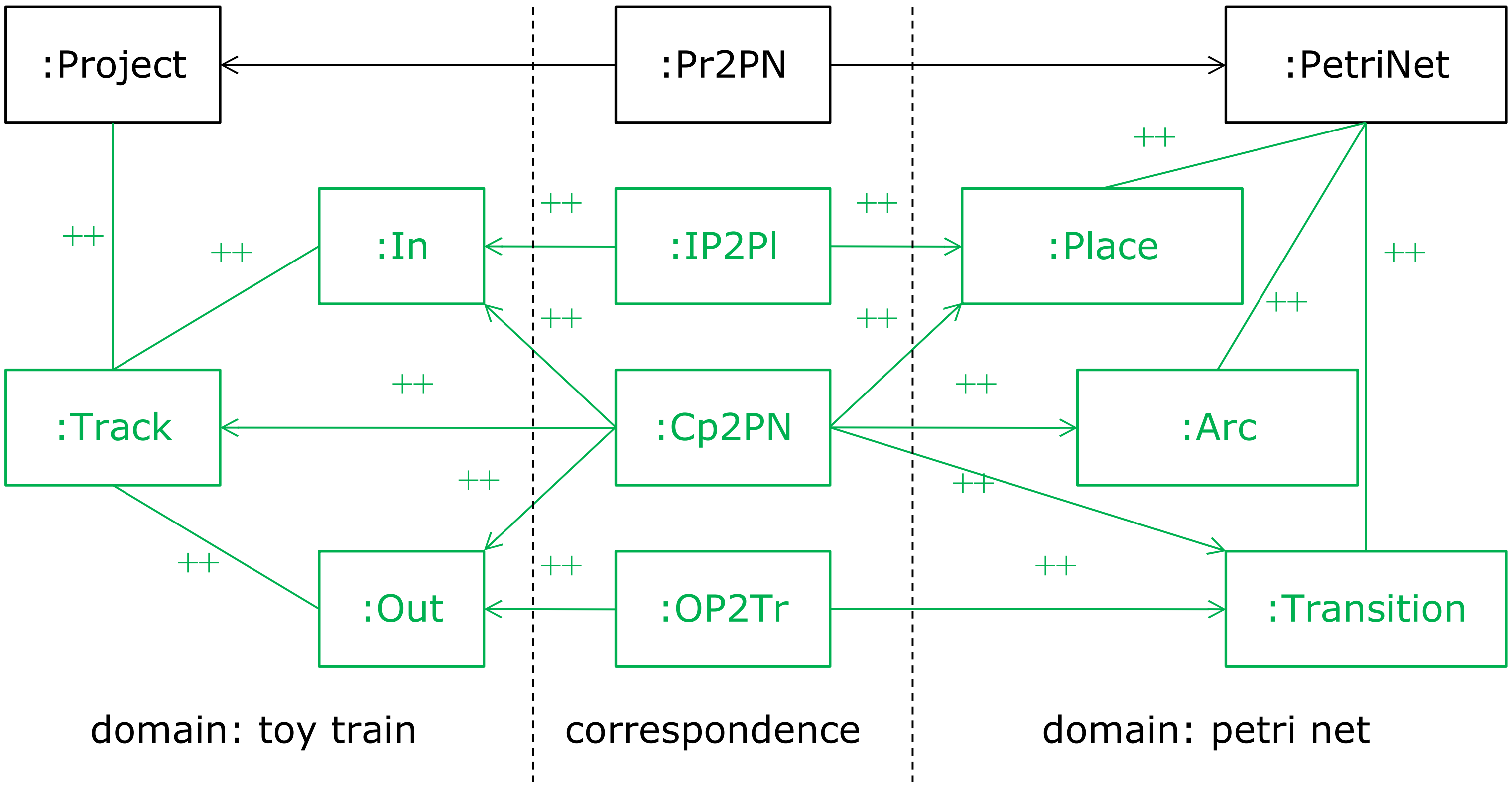
Step 4 – Deriving Rules from Model Pairs

Rail tracks to Petrinet example



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Restrictions of Tornado

Constraints

- Can be derived (e.g., equality if attribute values match), but:
  - What about boolean attributes?
  - What about more complex constraints (a.name == b.id)?

Negative Application Conditions

- May need additional annotations

Concrete Syntax (CS) restricts rules that can be specified

- If AS is less restrictive than CS (e.g., metaclasses with empty CS)

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Conclusion of (Experimental) Tornado Method

Textual (modelling) languages can be automatically extended with:

  - annotation support (This whole stuff is for free!)
  - other features (More stuff is for free as well! See e.g. [1])

- Rule specification using concrete syntax seems intuitive
- Combines benefits of specification by example (CS) and classic rule specification (precision)
- Debugging based on CS is enabled
- More annotations may be needed, but can easily be added
- Metamodelling languages should support extensibility to its full extent

Looking for a student to combine Tornado with GrGen!

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The End: What Have We Learned

- Graph rewrite systems are tools to transform graph-based models and graph-based program representations
- MOFLON supports OCL queries and constraints
- TGG enable to bidirectionally map models and synchronize them
- Why can a TGG also be called a *metamodel mapping grammar?*
- Correspondances in models can be expressed by annotations

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