Towards Rigorously Faking Bidirectional Model Transformations

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Unidirectional model transformations

- translate models in some source language to models in some target language

- maintain some sense of consistency between the models

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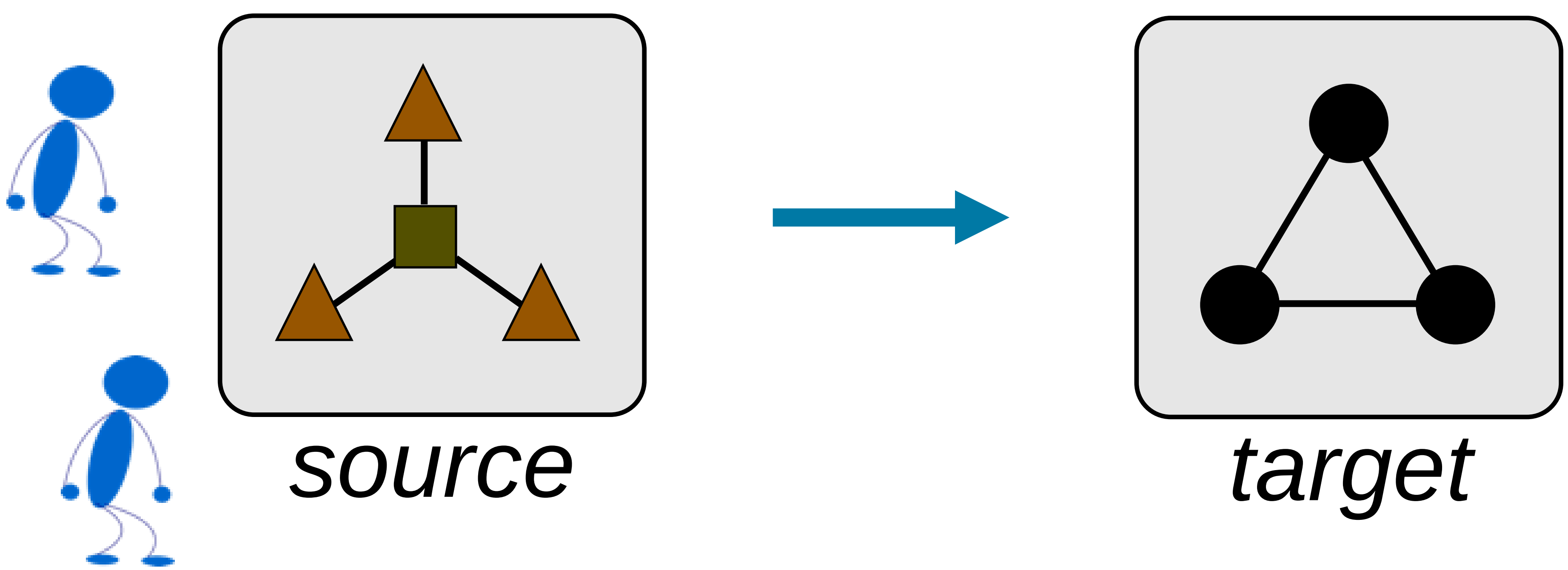
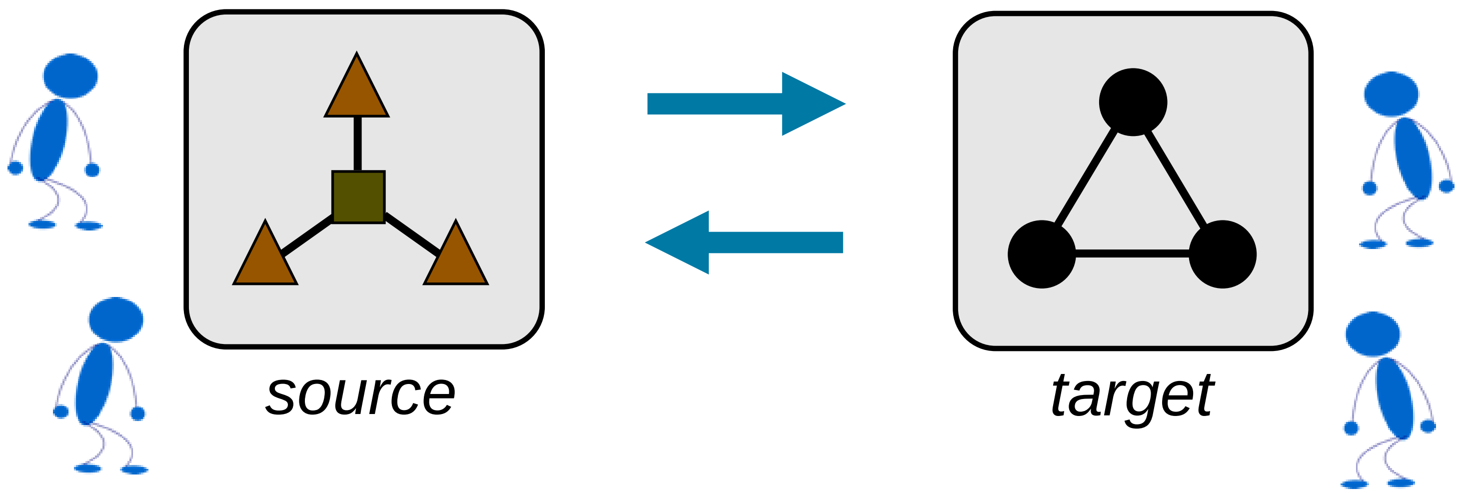


What if users modify both models?

- in some scenarios, users may modify both models in concurrent engineering activities



- e.g. database view problem, system integration

- maintaining consistency still important - but harder

Bidirectional transformations (bx)

- bidirectional model transformations (bx) simultaneously describe transformations in both directions
- compatibility of the directions guaranteed

  => *i.e. both directions maintain consistency of models*
- BUT: inherently complex and challenging to implement

  => *many model transformation languages do not support bx*

  => *others do, with conditions (e.g. bijective, TGGs)*

  => *QVT-R supports bx, but has an ambiguous semantics, and QVT-R tools don't exist*

Is there another way?

if a framework existed in which it were possible to write the directions of a transformation separately and then check, easily, that they were coherent, we might be able to have the best of both worlds

Stevens, P.: A landscape of bidirectional model transformations. In: GTTSE 2007.

“Faking” bx in epsilon

- Epsilon is a platform of interoperable model management languages

- no direct support for bx, but:

  => *languages for unidirectional transformations (ETL, EWL, EOL)*

  => *an inter-model consistency language (EVL)*

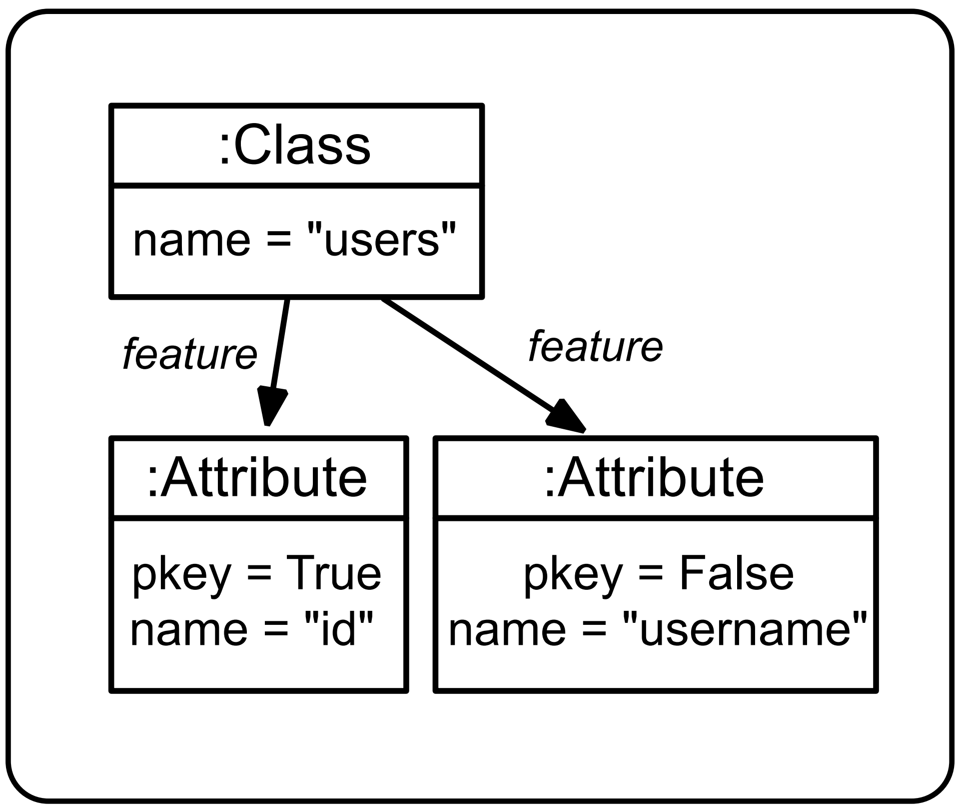
- bx can be faked in Epsilon by:

  (1) defining pairs of unidirectional transformations

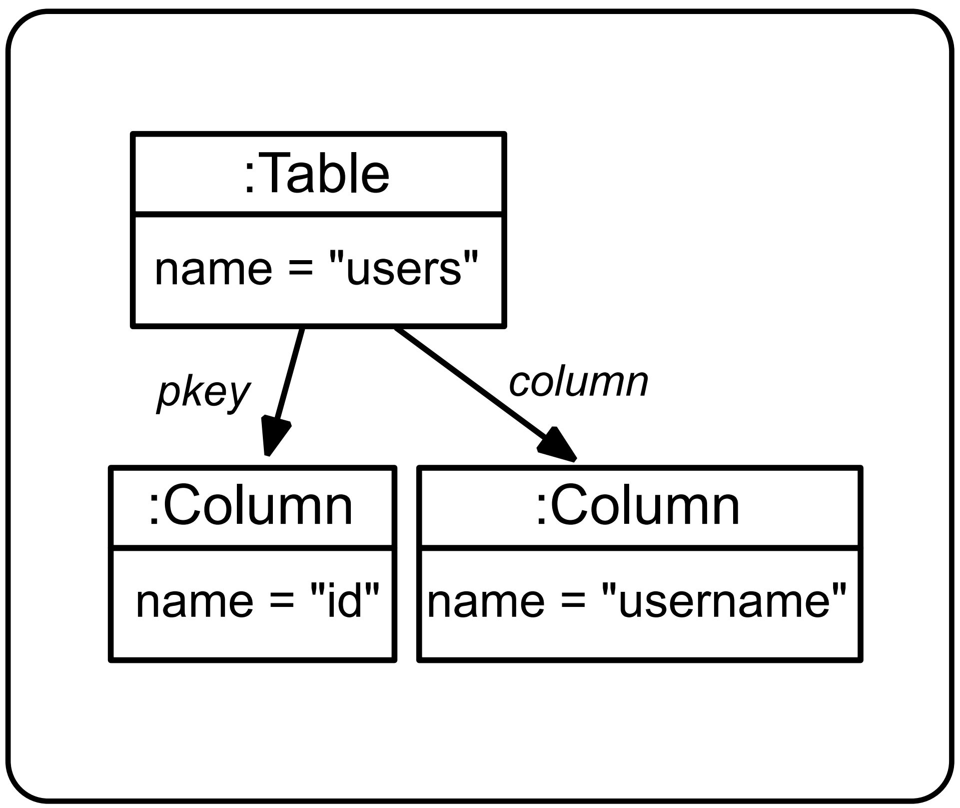
  (2) defining consistency via inter-model constraints

Class Diagrams to Relational Databases
(the forbidden example)

- two metamodels: class diagram and relational DB
- consistency defined in terms of a correspondence between the data (attributes) in the models



class diagram



relational DB

Example bx "faked" in Epsilon

- users of the models should be able to create new classes (or tables) whilst maintaining consistency

- first, we specify a pair of unidirectional transformations in Epsilon's update-in-place language

```
wizard AddClass {
 do {
   var c: new Class;
   c.name = newName;
   self.Class.all.first().contents.add(
        c);
 }}
```

```
wizard AddTable {
 do {
   var table: new Table;
   table.name = newName;
   self.Table.all.first().contents.add(
        table);
 }}
```

Example bx "faked" in Epsilon

- then, we specify and monitor inter-model constraints that express what it means to be consistent

```
context OO!Class {
 constraint TableExists {
   check : DB!Table.all.select(t|t.name
         = self.name).size() > 0
}}
```

```
context DB!Table {
 constraint ClassExists {
   check : OO!Class.all.select(c|c.name
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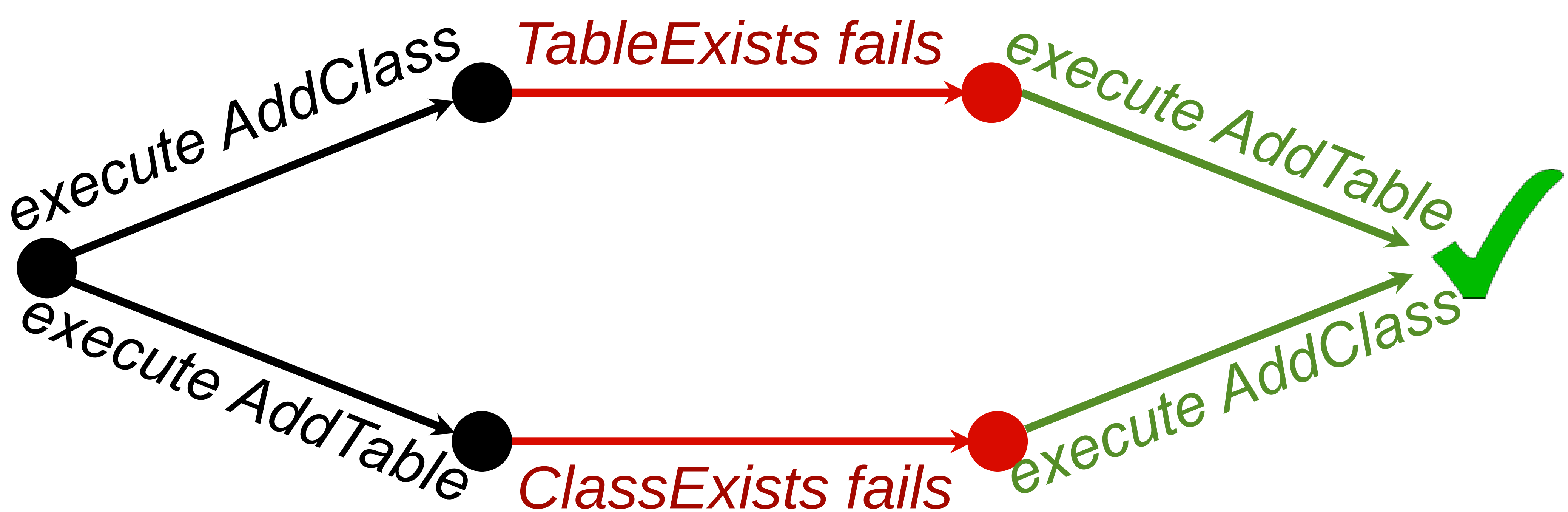

We didn't quite fake everything yet...

- fake bx lack the consistency guarantees that true bx have by construction

- what does this mean?

  => *compatibility of the directions might not be maintained (e.g., discovered when checking consistency)*

  => *repair transformations might not actually restore consistency*

- our example is obviously compatible, but we should be able to check this easily and automatically

Our proposal: exploit graph transformation verification techniques to check compatibility

- graph transformation (GT) is a computation abstraction

  => state is represented as a graph

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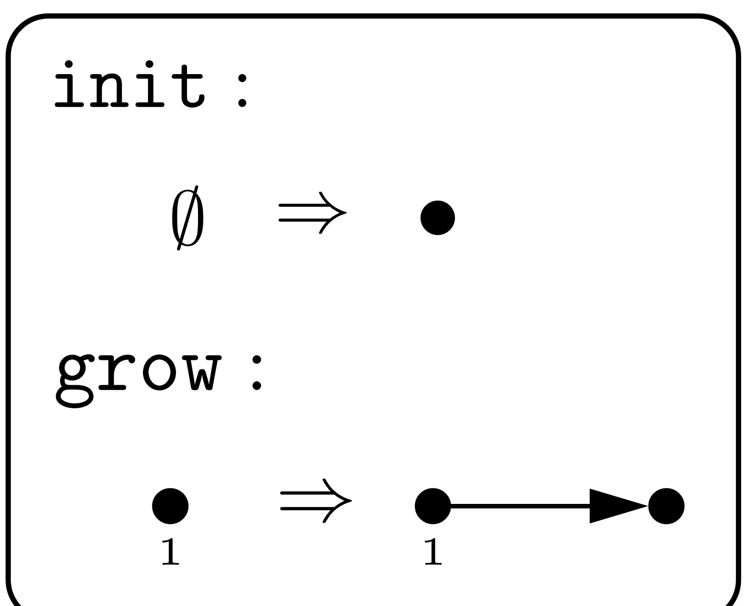

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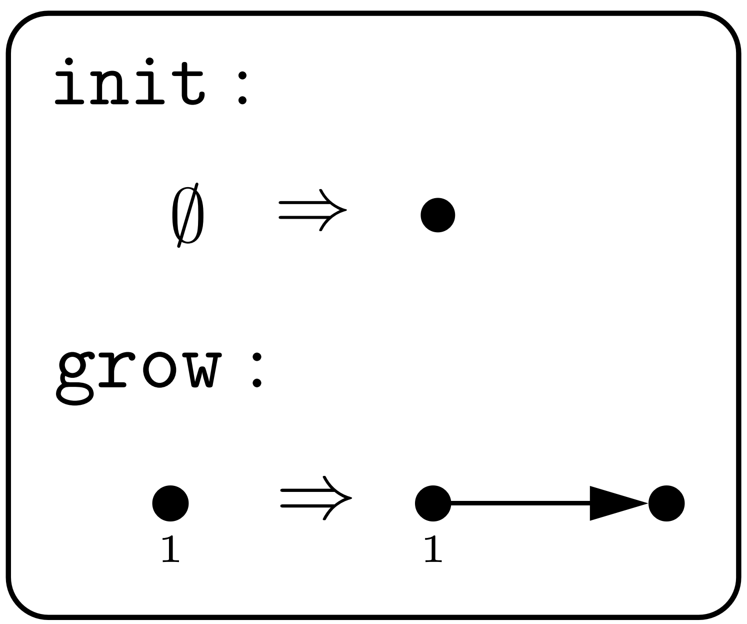
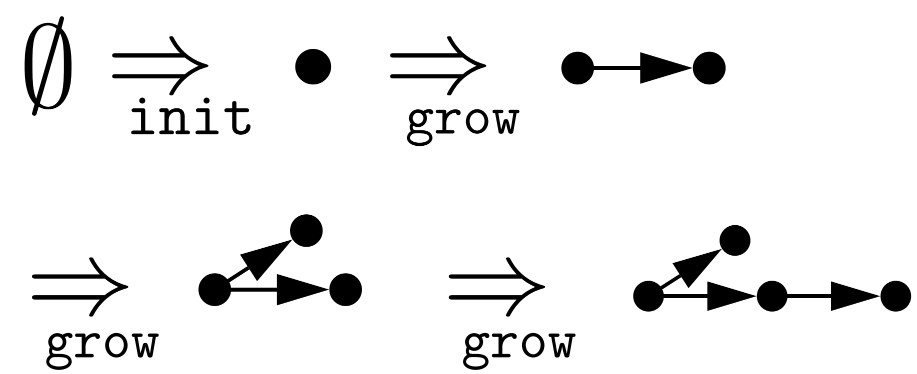
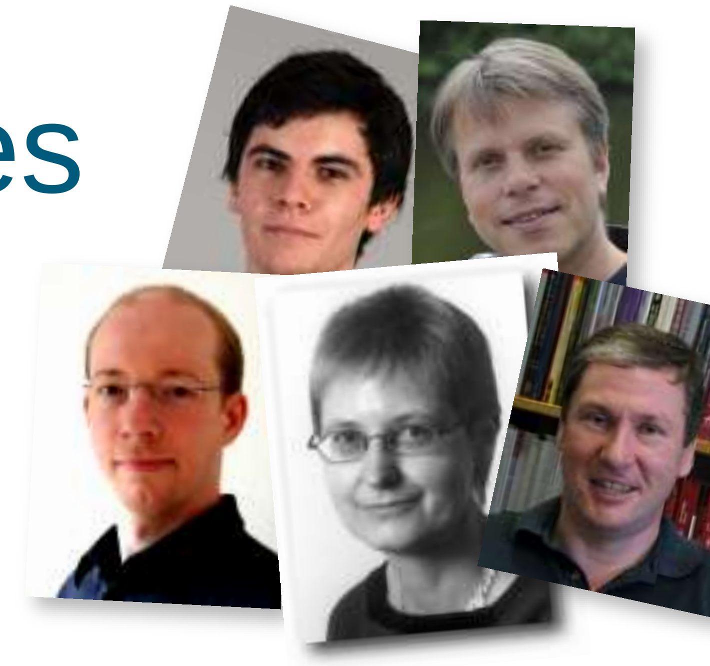




GT verification techniques



- functional correctness of GT rules can be verified in a weakest precondition style
- pre- and postconditions are expressed in the graph-based logic of nested conditions, equiv. to FO logic
- roughly, to verify {pre} P {post}:

GT rules
P

nested conditions
pre & post

calculate WP(P, post)

does WP(P, post) => pre ?

How we will rigorously fake bx

- translate the unidirectional transformations to GT rules
  => *denoted P_S and P_T*

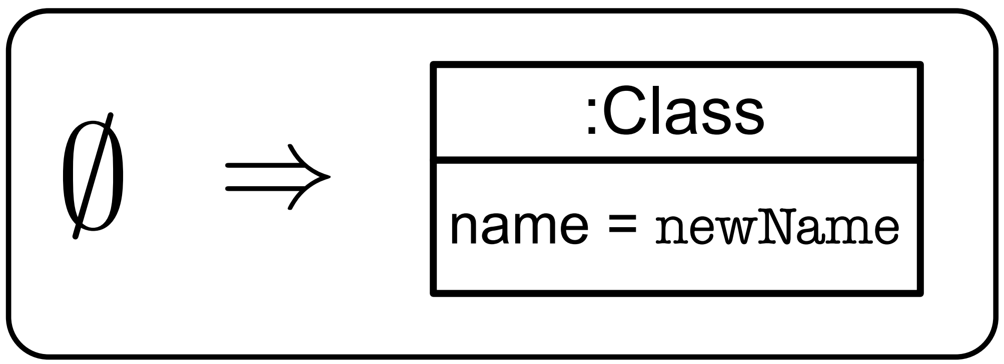
- translate the inter-model constraints to nested conditions
  => *denoted evl*

- automatically discharge the following specifications using the weakest precondition calculi

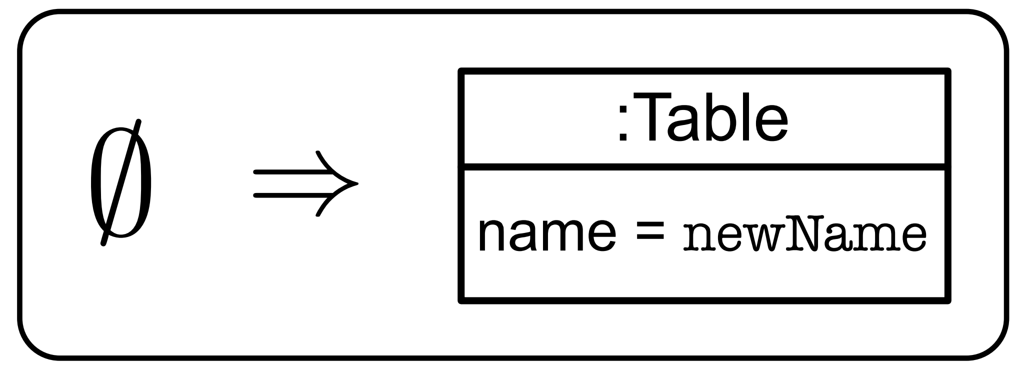
$\boxed{\{evl\}\ P_S;\ P_T\ \{evl\}}$ $\boxed{\{evl\}\ P_T;\ P_S\ \{evl\}}$

Proving consistency of our CD/DB bx

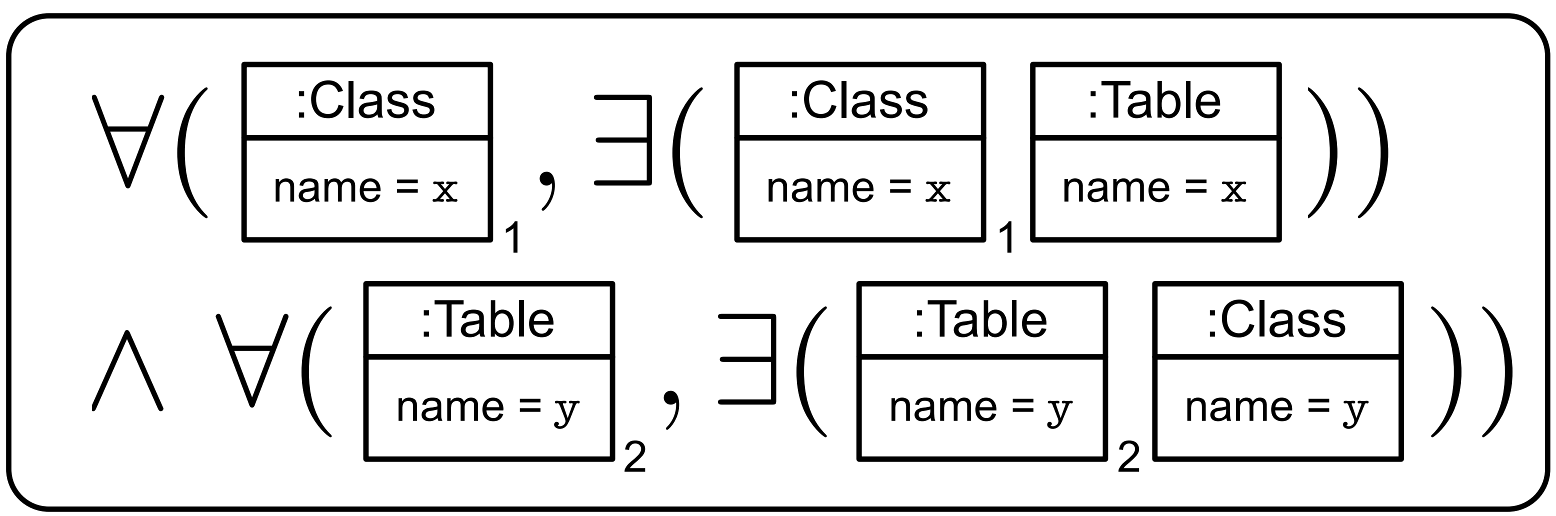
P_S



P_T



evl



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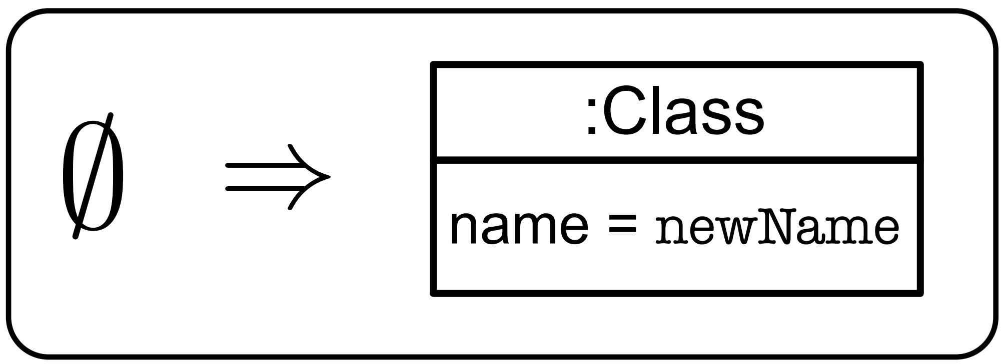

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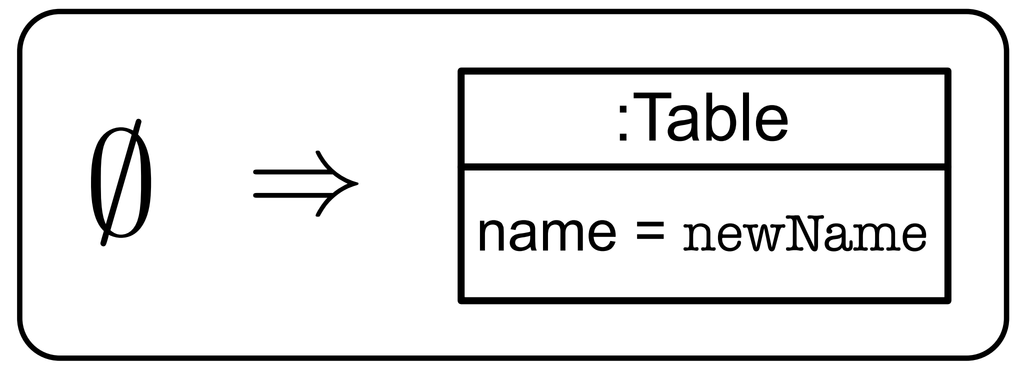

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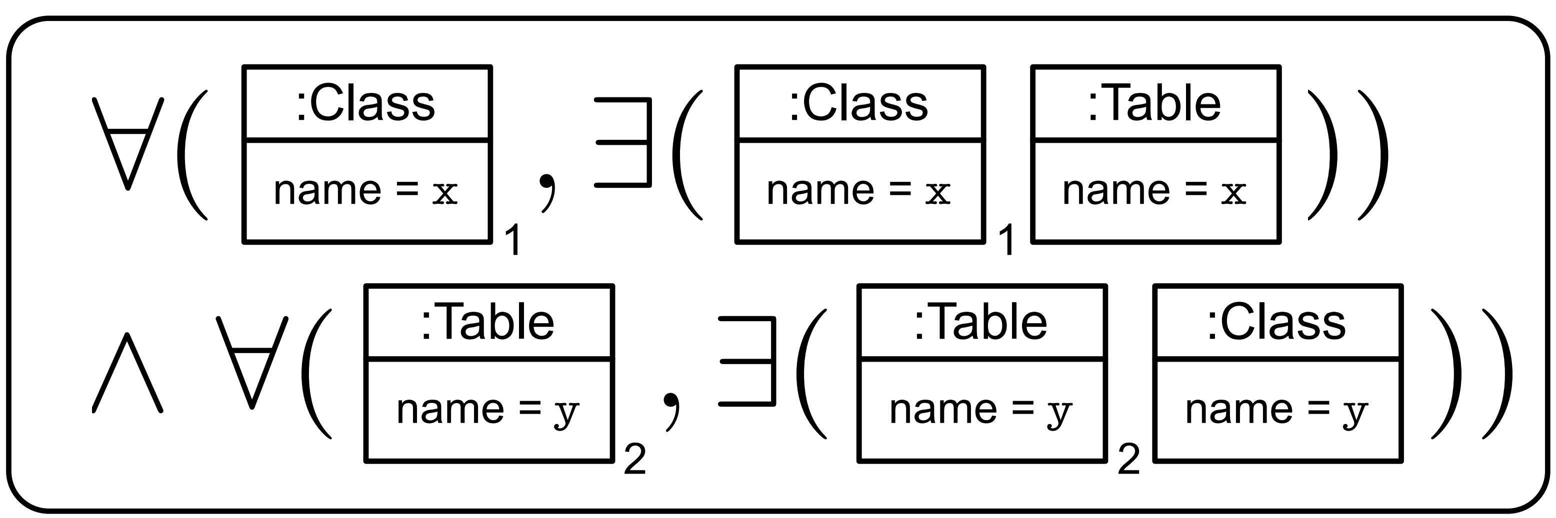
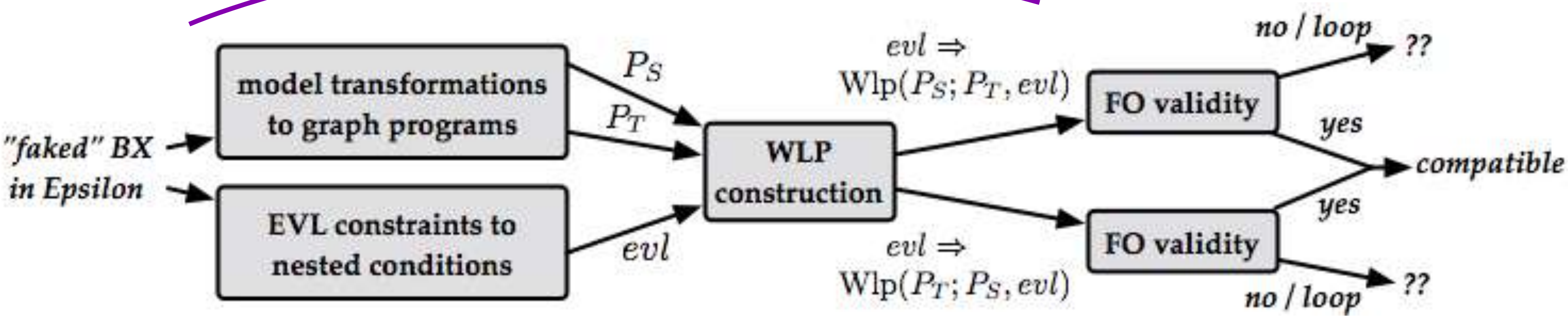


✓ *compatible:* *WP*(P_S;P_T,evl) ≡ *WP*(P_T;P_S,evl) ≡ evl

Putting it all together

we need to do this bit



exploit existing theorem provers here

Our next steps

- identify a selection of bx case studies
- fake them in Epsilon, manually translate them into GT rules and nested conditions, and verify compatibility
- implement the translations for an expressive subset of the Epsilon languages; implement the WP calculation
- challenges and open questions:
  => *finding counterexamples (e.g. using GROOVE)*
  => *theoretical / practical limitations (e.g. is FO expressive enough?)*

In summary

- bx simultaneously describe transformations in both directions - compatible by construction
- but they are inherently complex and challenging to implement
- can be faked in Epsilon as pairs of unidirectional transformations and inter-model consistency constraints
- we will leverage GT proof technology to obtain compatibility guarantees for faked bx