Advanced Topics in Software Engineering (02265)

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V. Transformations

Overview

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1. Model to Text Transformation (M2T)
   (JET → last week)

2. Model to Model Tranformation (M2M)
   (TGG → today)

3. Other approaches
   (QVT, ...)

4. Overview and classification

→ Is there a fundamental difference between M2T and M2M?

→ Differences between different M2M technologies!

2.1. Motivation

Up to now:

- Use of modelling notations (M1)!
- Development of modelling notation (M2)!
- Generate code (or other text) from models!

How do we

- Transform one model into another?
- Transform changes in the target model back to the source model?
- Keep different models consistent (synchronization)?
- Identify changes and transfer them to other models?
  (Version control, Identify design decisions, ...)

Is there a difference to a transformation to text?

2.2. Background

- Grammars, a reminder!
  (and two different purposes)

- Graph grammars
  (same thing just with graphs)

Example: Grammar

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E	→	T | E + T	Expression
T	→	F | T * F	Term
F	→	I | N | (E)	Factor
I	→	a | … | z | Ia | … | Iz	Identifier
N	→	0 | … | 9 | N0 | … | N9	Number

Example: Gramm

Left-hand side (of a rule)

Terminal symbols: +, *, (,), a, … z, 0, …, 9

Non-terminal symbols: E, T, F, I, N

E	→	T | E + T	
T	→	F | T * F	Term
F	→	I | N | (E)	Factor
I	→	a | … | z | Ia | … | Iz	Identifier
N	→	0 | … | 9 | N0 | … | N9	Number

Right-hand side (of a rule)

Meta-symbols: →, |

Meta-meta-symbol: …

Example: Parsing

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x + y * (x + 1)

E → E + T → T + T → F + T → I + T → x + T →
x + T * F → x + F * F → x + I * F →
x + y * F → x + y * (E) → x + y * (E + T) →
x + y * (T + T) → x + y * (F + T) →
x + y * (I + T) → x + y * (x + T) →
x + y * (x + F) → x + y * (x + N) →
x + y * (x + 1)

Grammars

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- A grammar consists of
  - rules and
  - one axiom (a non-terminal)
- A rule says how, within a character sequence, a sub-sequence can be replaced by another sequence

  Technically, $E \rightarrow T \mid E + T$ represents two rules!

- Grammars are often restricted to character sequences of non-terminals on the left-hand side
- In context-free grammars (*cfg*), the left-hand side consists of exactly one non-terminal symbol

Grammars: Use 1

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- can be used to define the legal syntax of a programming language or some other textual language
- can be used to build parsers and for building the syntax tree

  → Formal languages
  → Compiler construction
  → Parsing theory

  → Xtext

- In this sense, ”grammars are meta-models” or ”meta-models are grammars”

Another example: ”Grammar”

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$\#< \;\rightarrow\; \#>$

$a< \;\rightarrow\; <a$

$>a \;\rightarrow\; a>$

$>\# \;\rightarrow\; <\#$

What does that “grammar” do?

Another example:

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#>aaaaaa# → #a>aaaaa# → #aa>aaaa# → #aaa>aaa# →
#aaaa>aa# → #aaaaa>a# → #aaaaaa># → #aaaaaa<# →
#aaaaa<a# → #aaaa<aa# → #aaa<aaa# → #aa<aaaa# →
#a<aaaaa# → #<aaaaaa# →
#>aaaaaa# → ...

”Grammar”: Use 2

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- No axiom (just a ”start configuration”)

In this context, the “grammar” is typically called “rewriting system”.

- No distinction between terminals and non-terminals (conceptually, all symbols can be considered to be terminals; technically, all symbols can be considered to be non-terminals)

- The purpose is not parsing a string; it is about ”defining behaviour”; the string is just the current state (→ Markov algorithms)

Traditionally, the “algorithms” would be required to terminate; but, if they don’t, it just defines infinite behaviour (reactive systems).

Background

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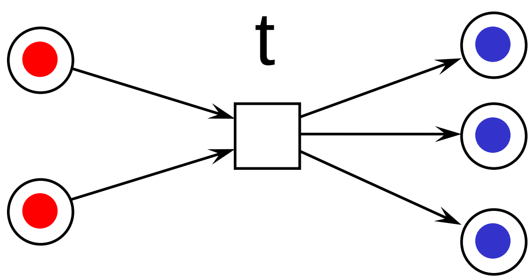
- Grammars, a reminder!
  (and two different purposes)

- Graph grammars
  (same thing just with graphs)

Example

Reminder: Firing rule of Petri nets



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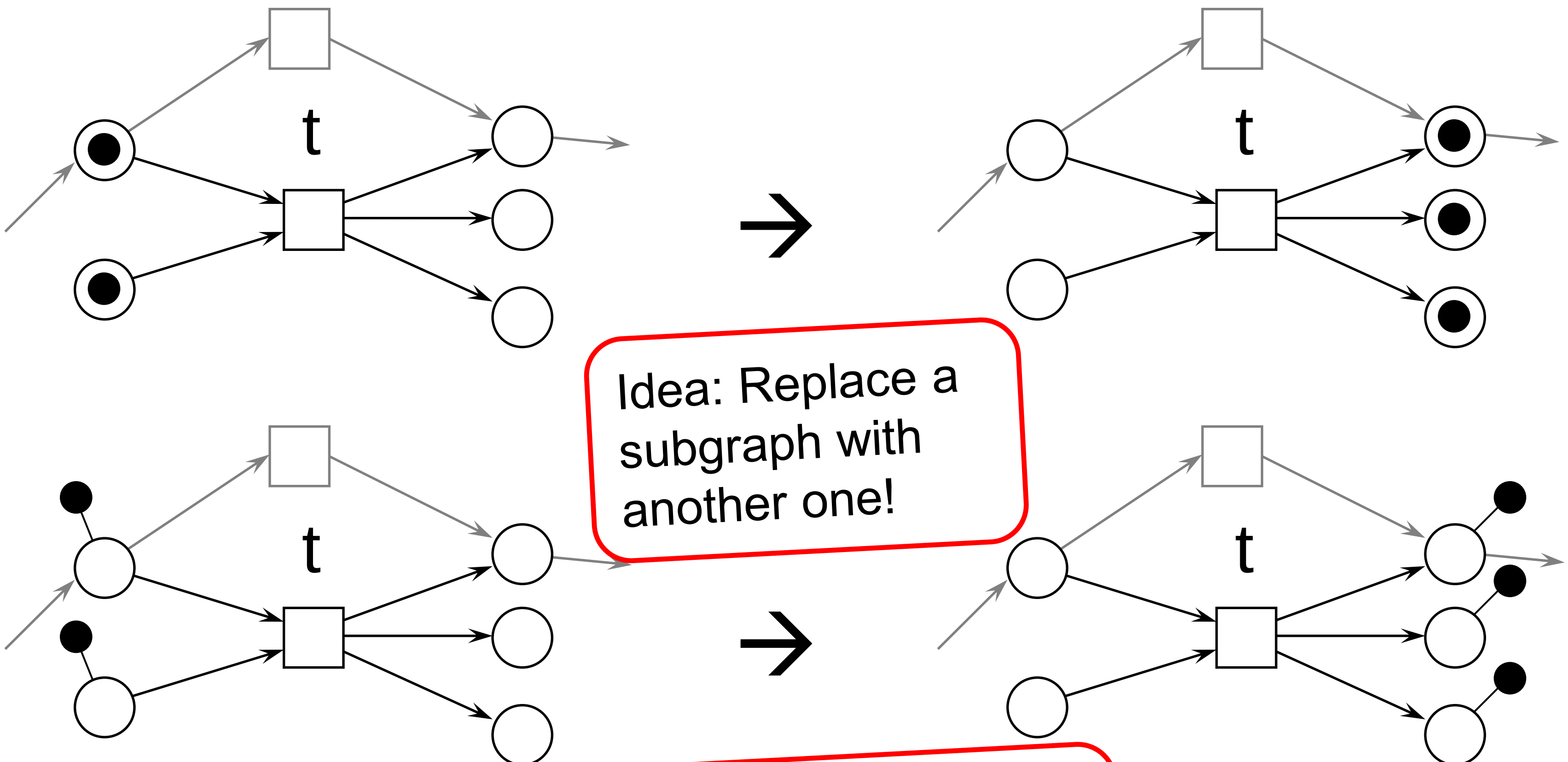
Firining rule of a Petri net transition



Idea: Replace a subgraph with another one!

What is the same on the left-hand and the right-hand side?

Example

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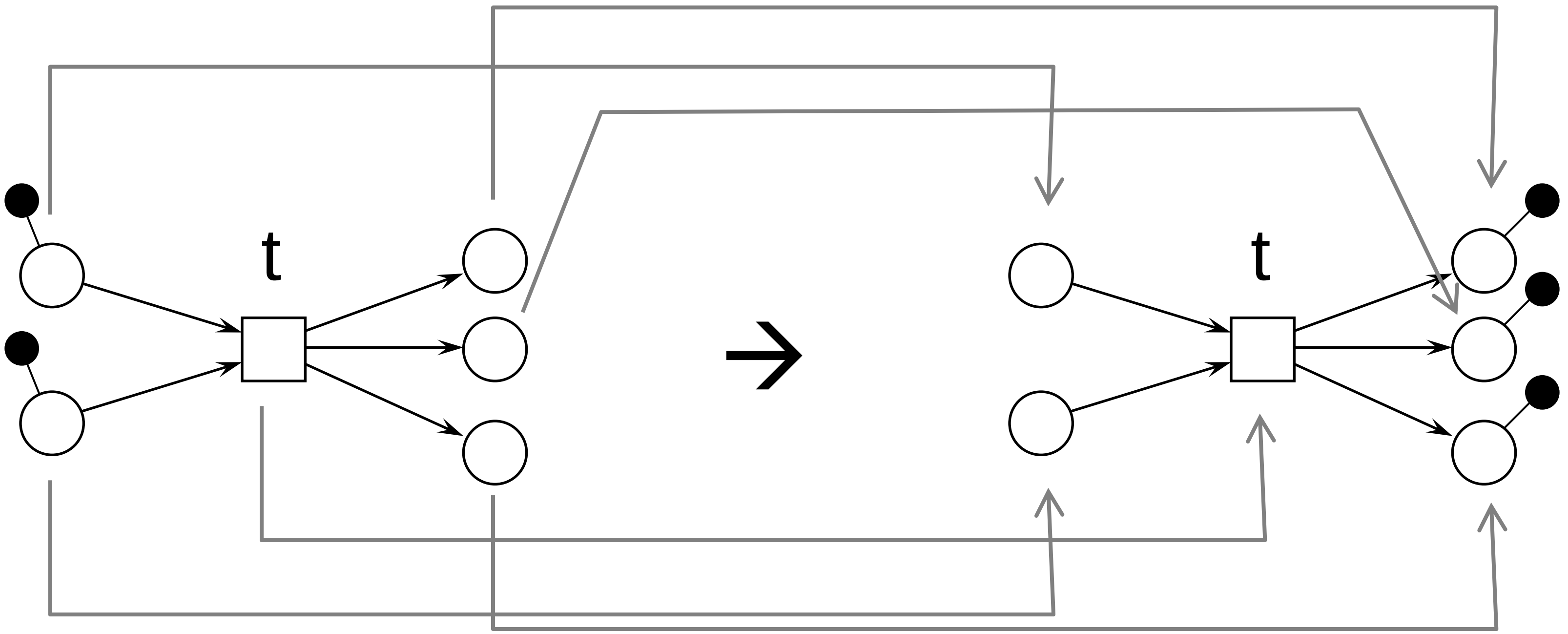
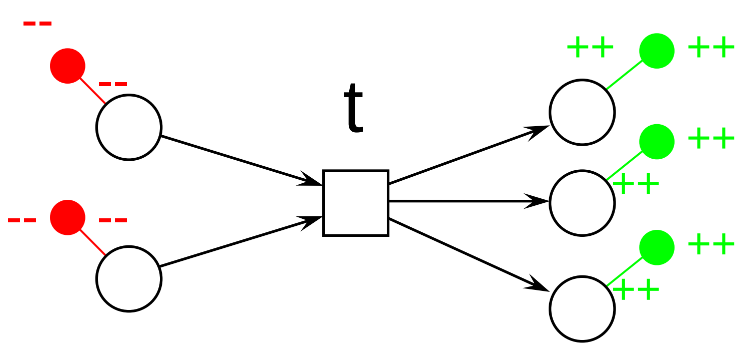
Firining rule of a Petri net transition as a graph grammar rule



Could be indicated by a mapping (also between the arcs).
For humans “mostly obvious” ☺

Firing of Petri nets

Different representation: single graph, indicating in colours (and labels) what does not change, what is deleted (--) and what is added (++):

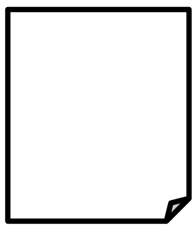


Exactly the same information as on pervious slide: just more concise

This is “Use 2” of graph grammars (defining evolving behaviour).

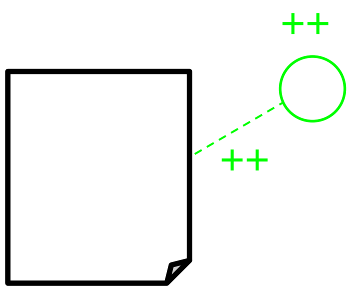
Use 1:

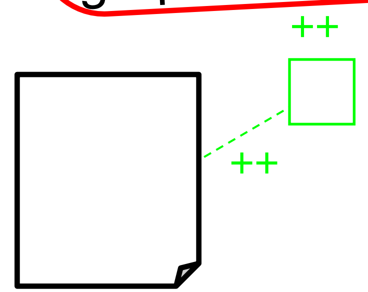
Defining the syntax of Petri nets:

Axiom: 

Note: In the tool that we are using, all nodes of the axiom will be "green" (++) nodes.

Which interpretation makes more sense, depends on whether you want to consider the axiom as a rule or as a graph.

Rule 1: 

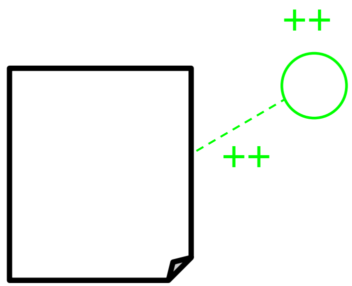
Rule 2: 

Use 1:

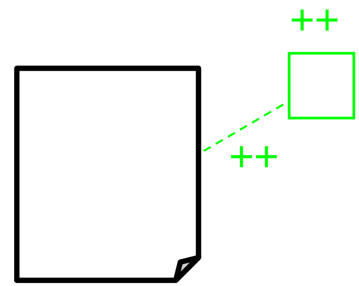
This graph grammar defines the syntax of Petri nets. It can be used to generate or parse a syntactically correct Petri net.

Defining the syntax of Petri nets:

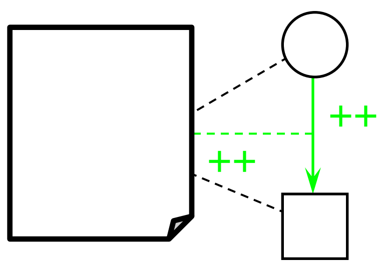
Rule 1:



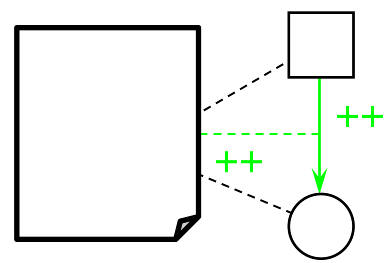
Rule 2:



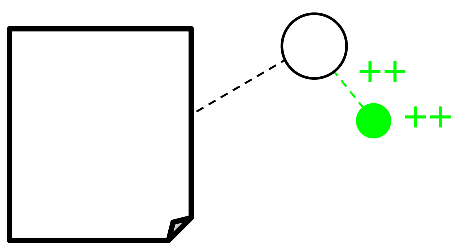
Rule 3:



Rule 4:



Rule 5:



Note that this is not the (main) purpose of GGs here; the example should just illustrate the “Use 1” of GGs.

2.3. Triple Graph Grammars (TGGs)

- Using graph grammars for defining the relation between models (in a special way),
- for transforming them accordingly, and
- keeping the resulting models consistent.

Outline

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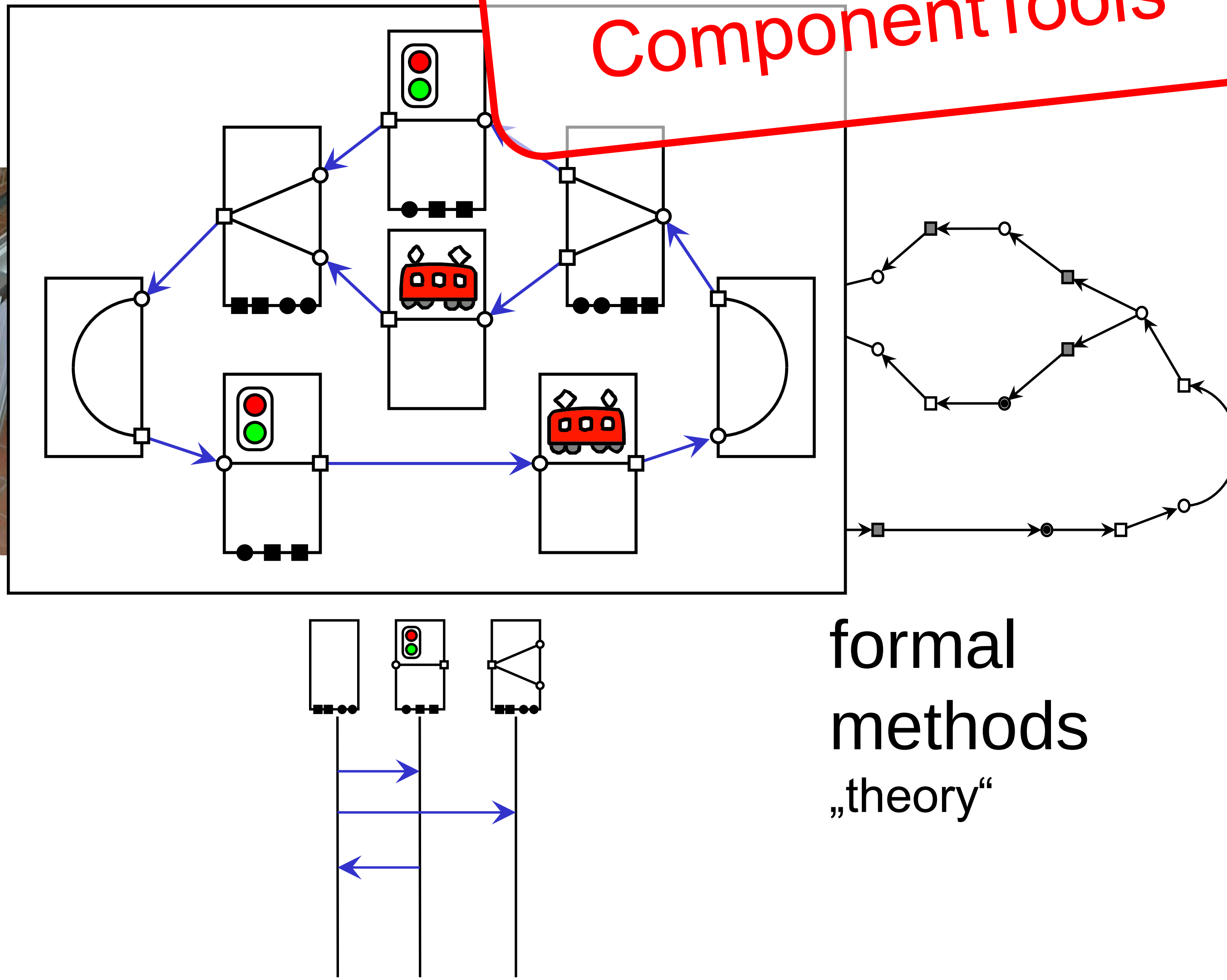
- Example
- Semantics
- Strength
- Problems and Weaknesses
- Extensions and Open Issues

An Example

Borrowed from ComponentTools

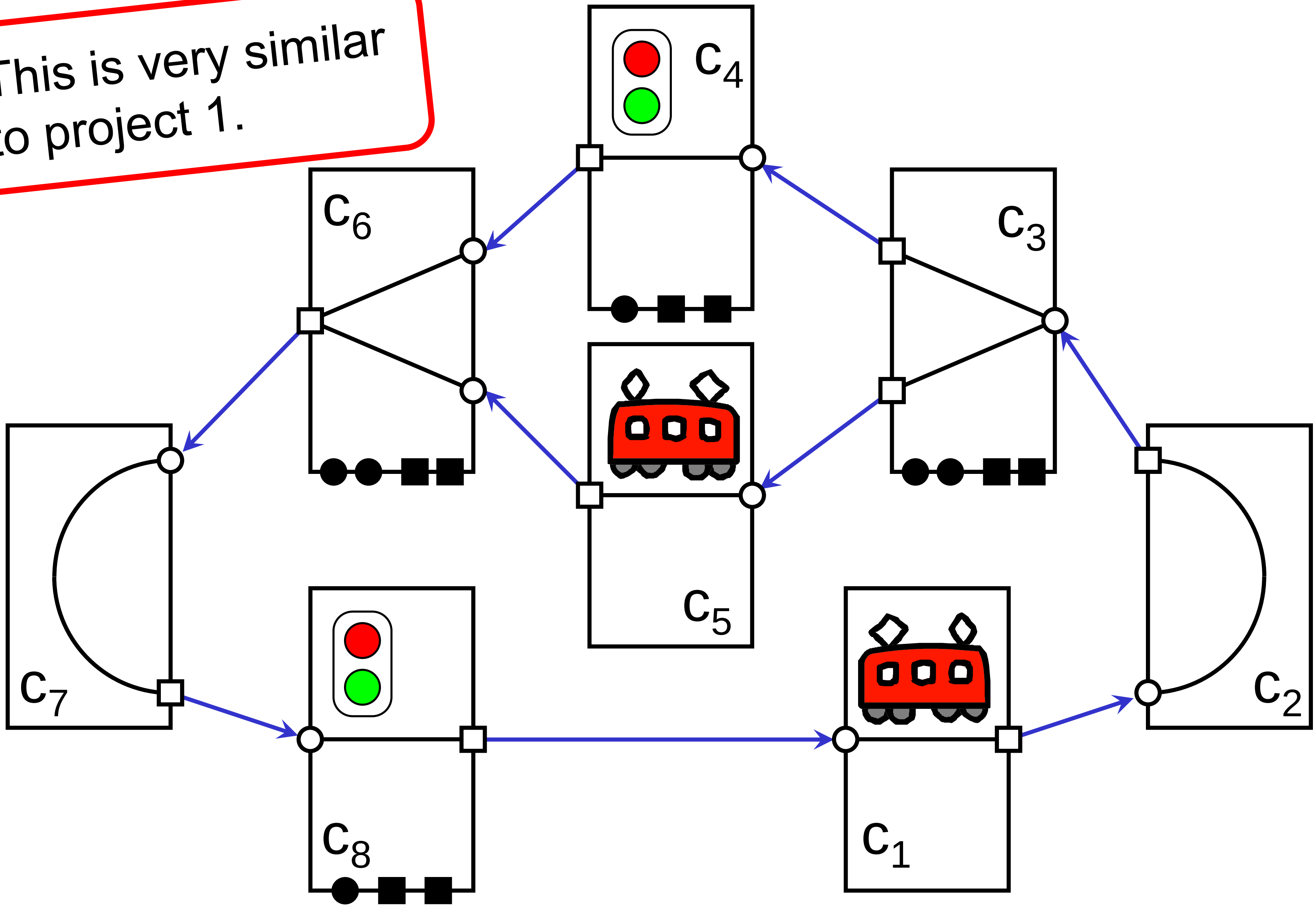
engineer
„practice“



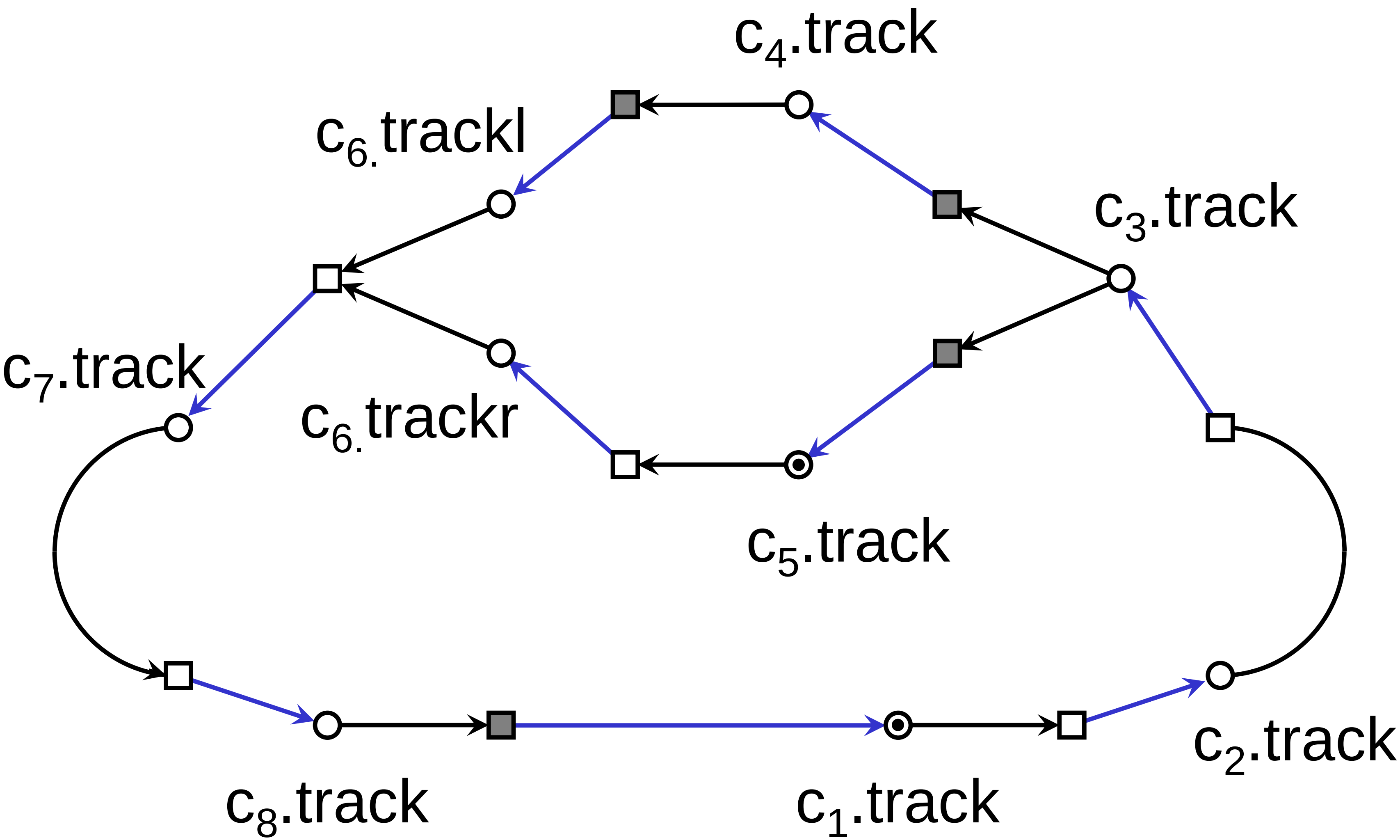
formal
methods
„theory“

Project Plan

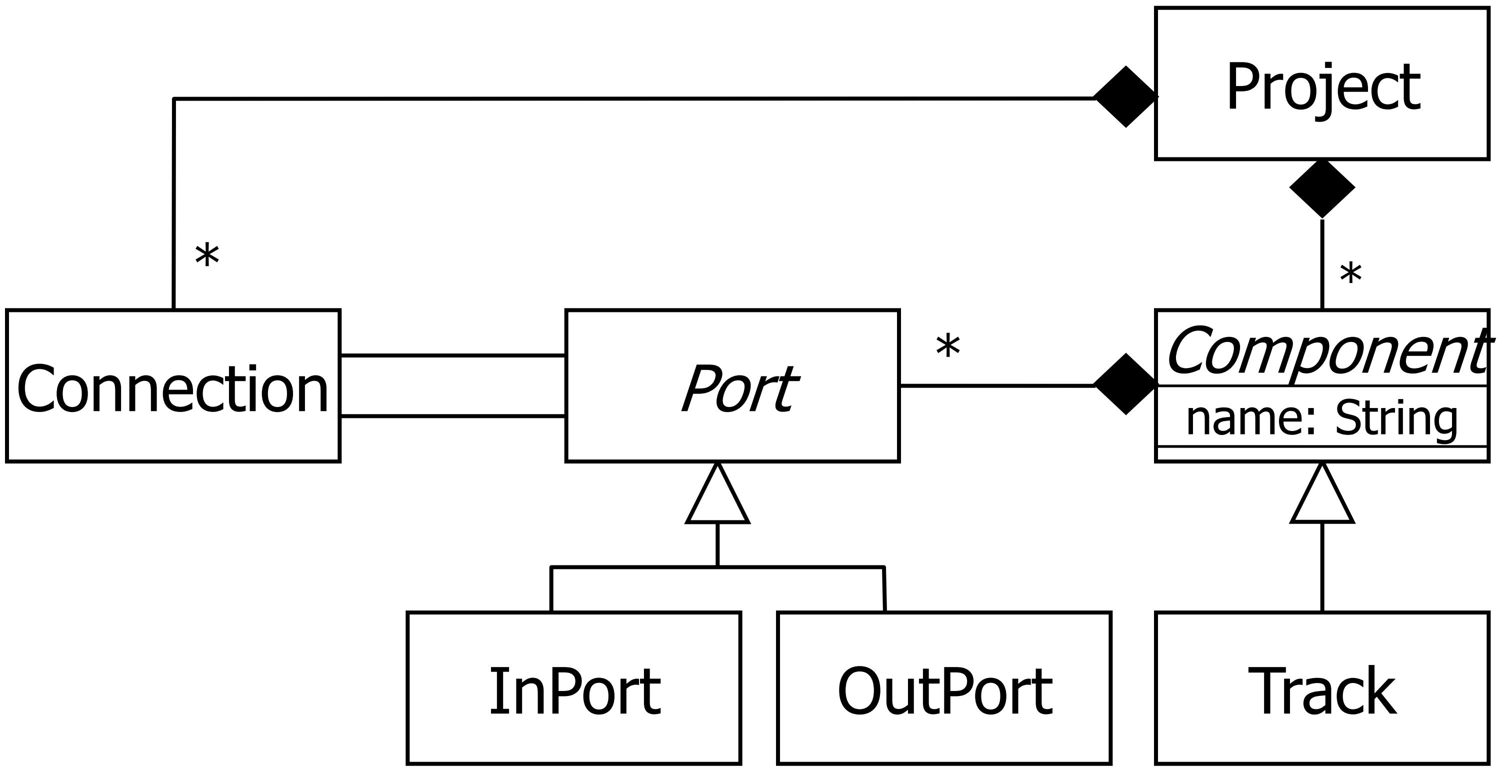
This is very similar to project 1.



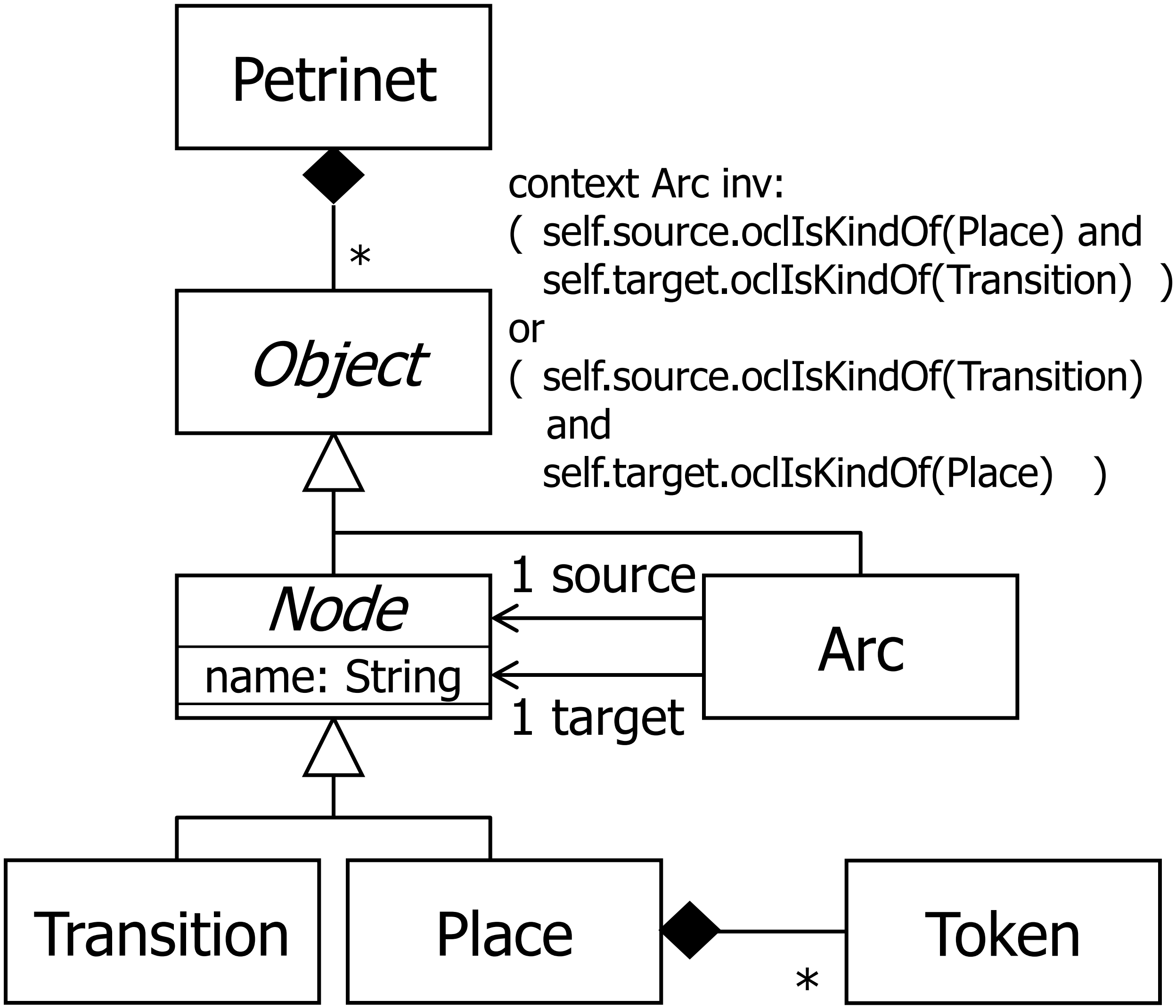
Corresponding Petri Net



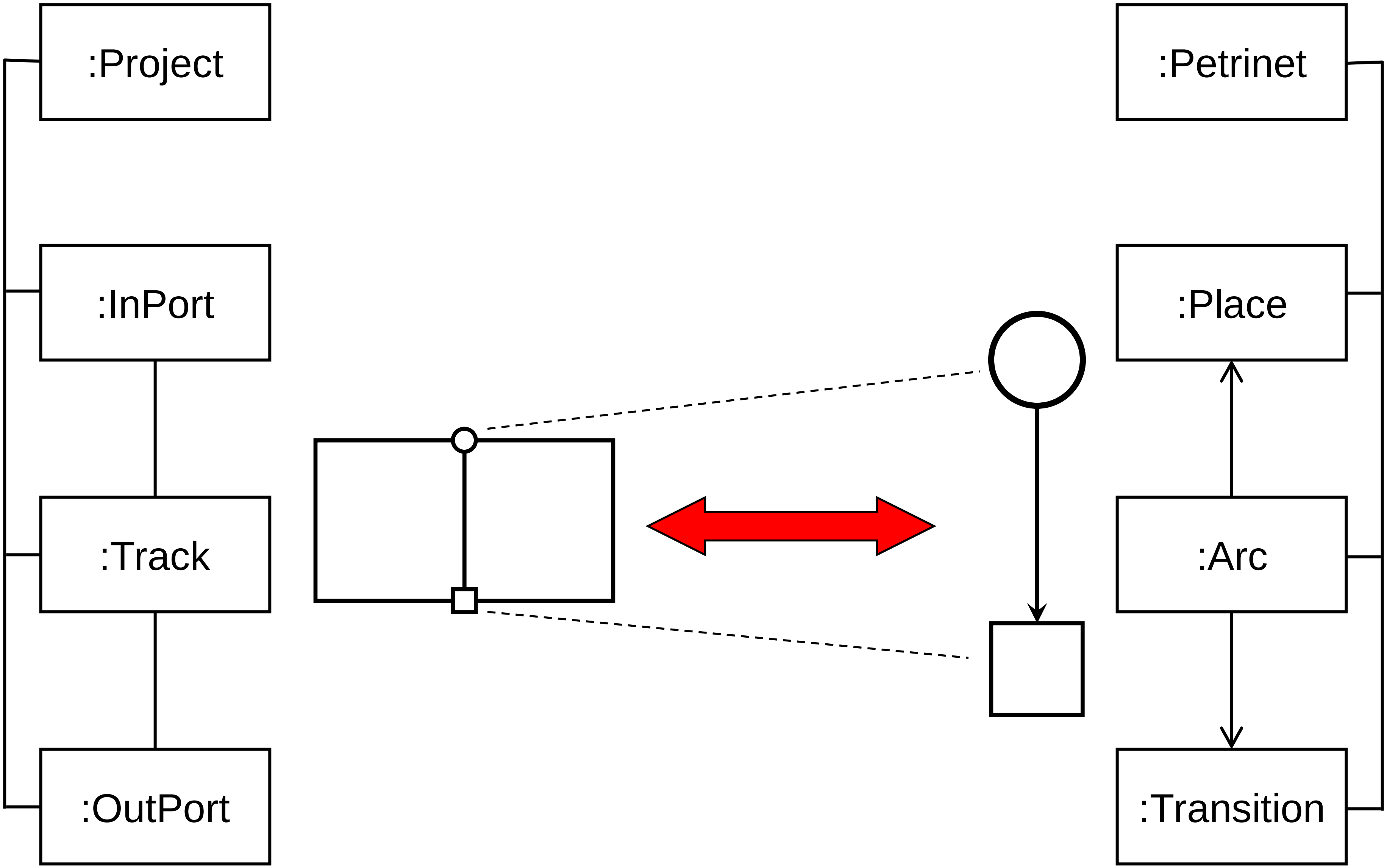
Project: Meta-model



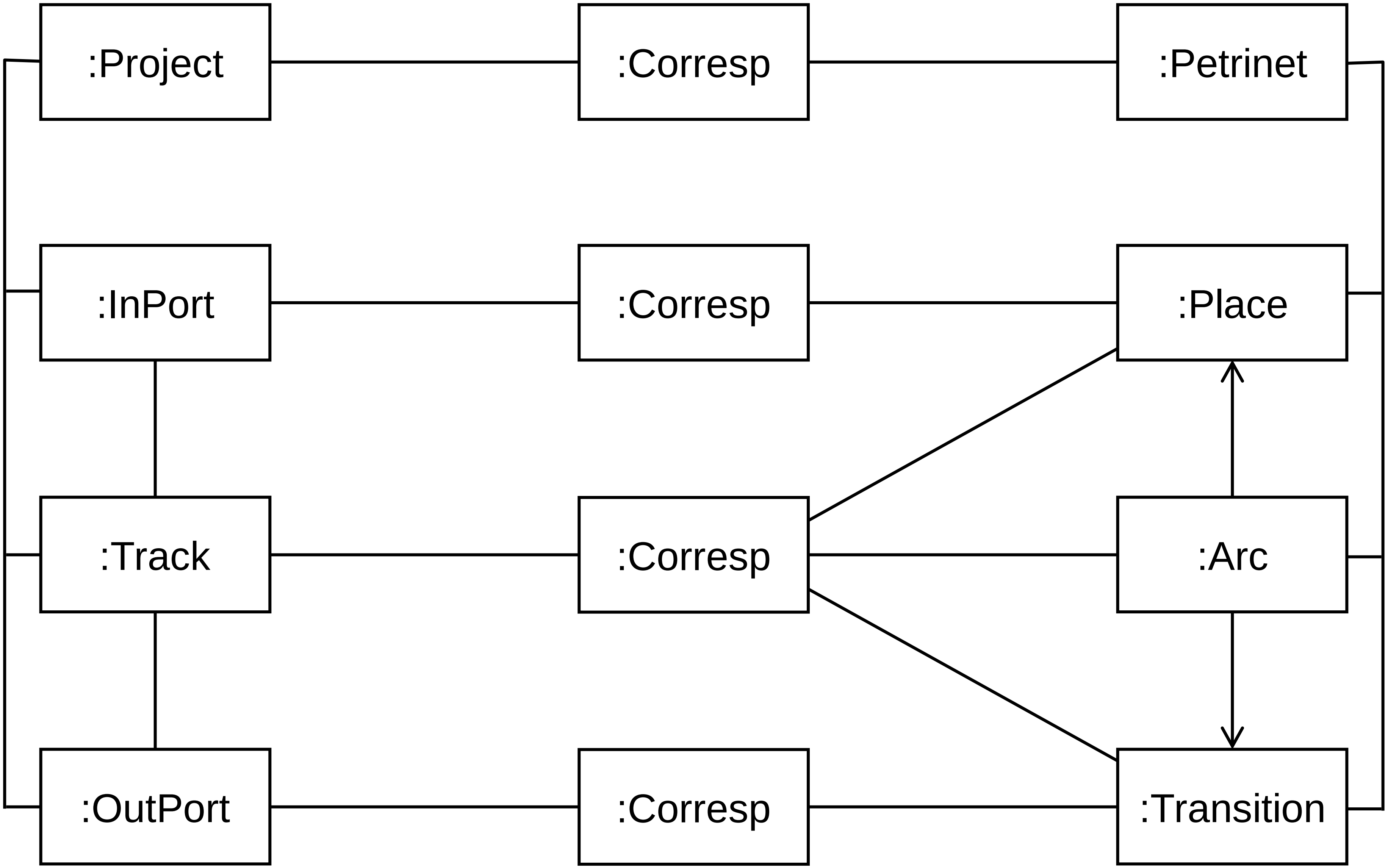
Petri nets: Meta-model



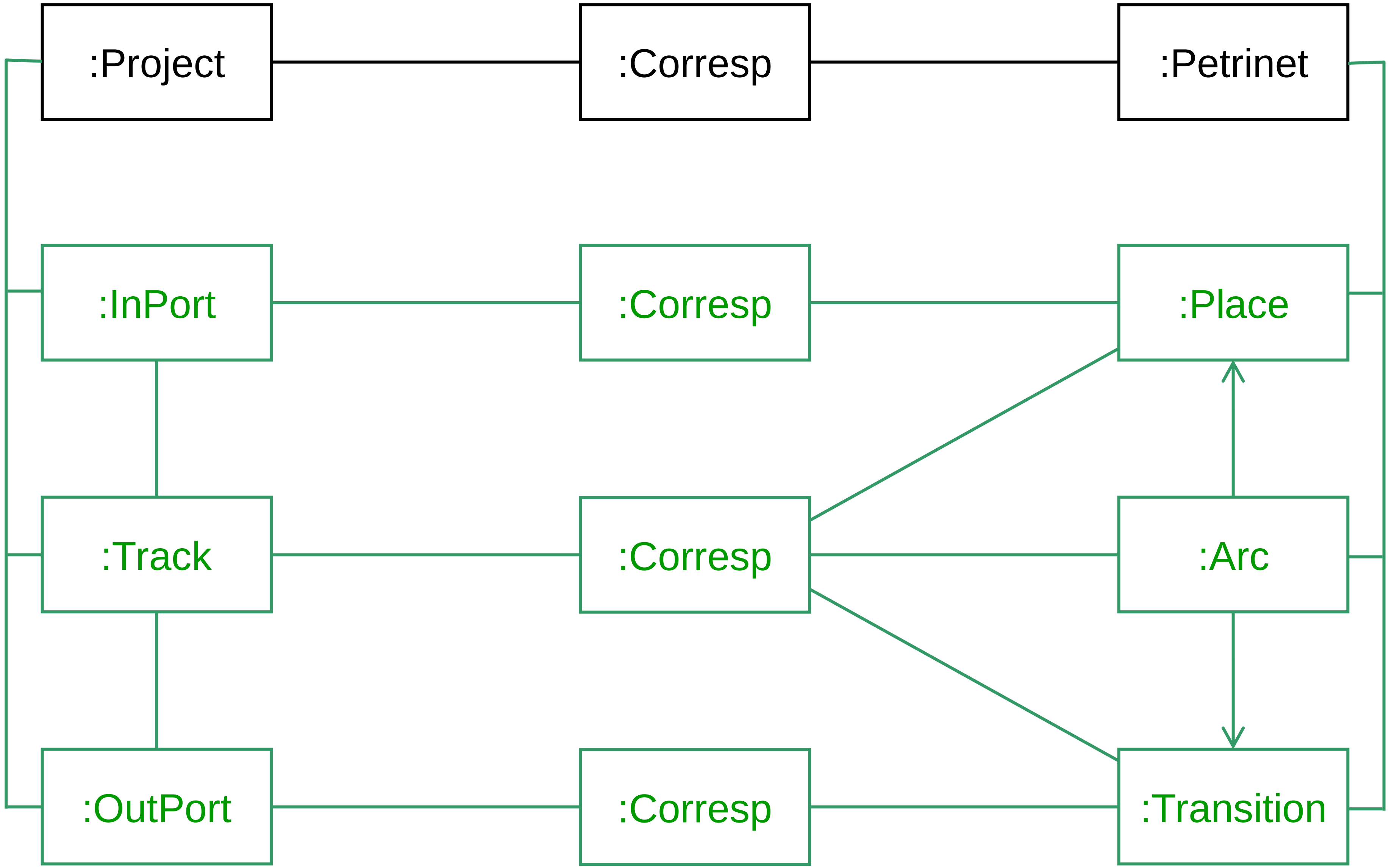
Transformations



Transformations



Triple Graph Grammar Rule



TGG-Rule Application

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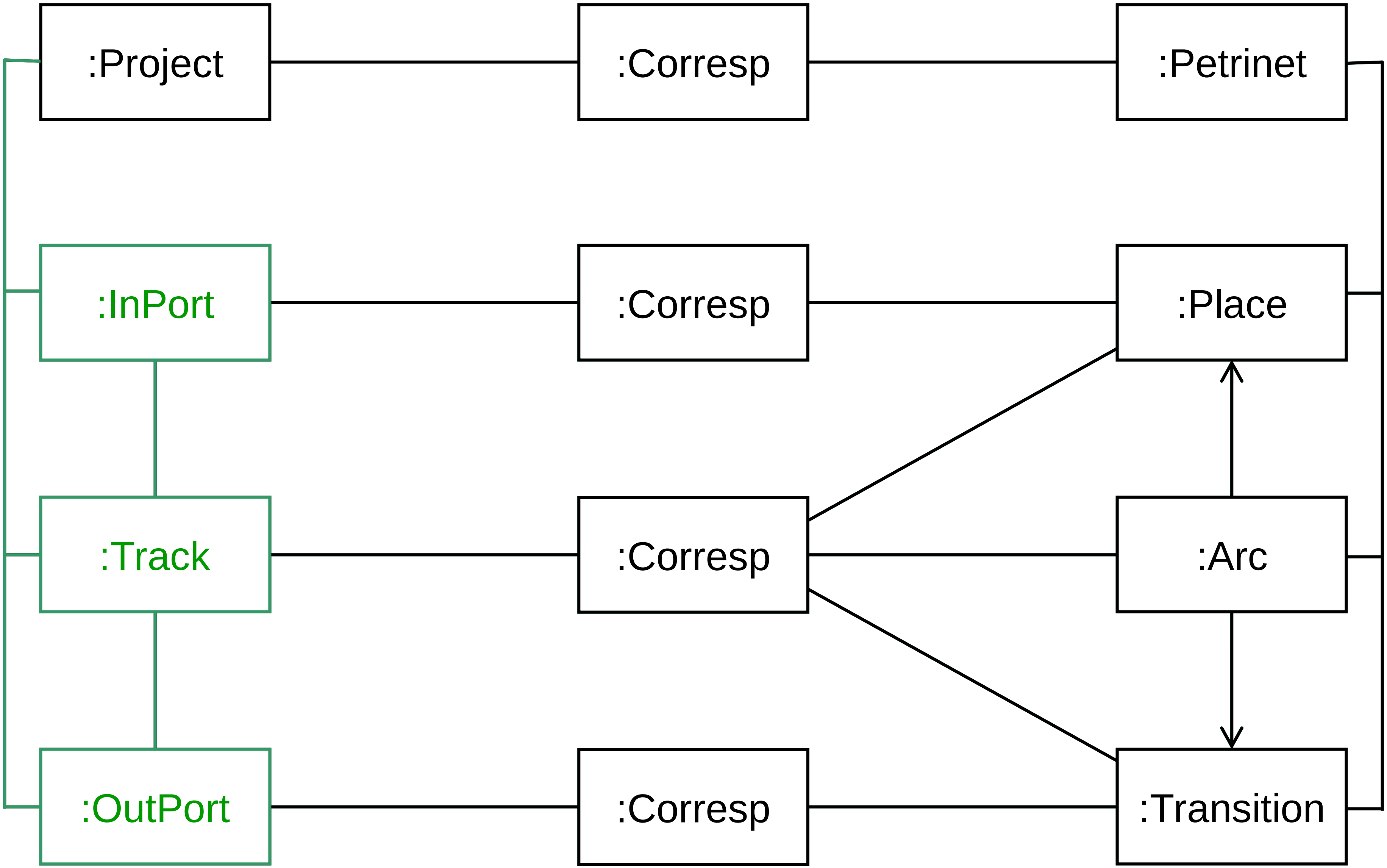

Transf. of connection

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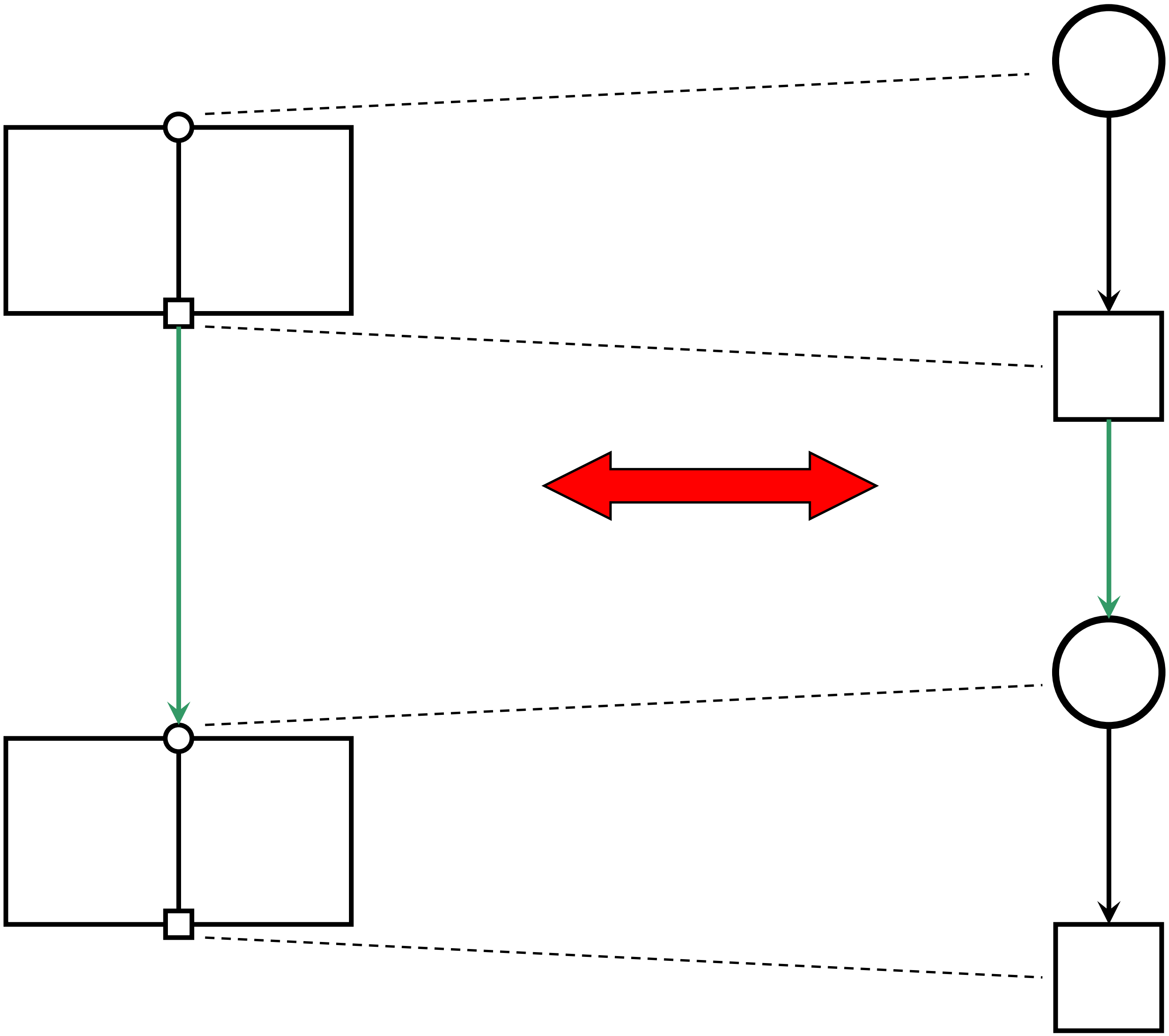

Transf. of connection

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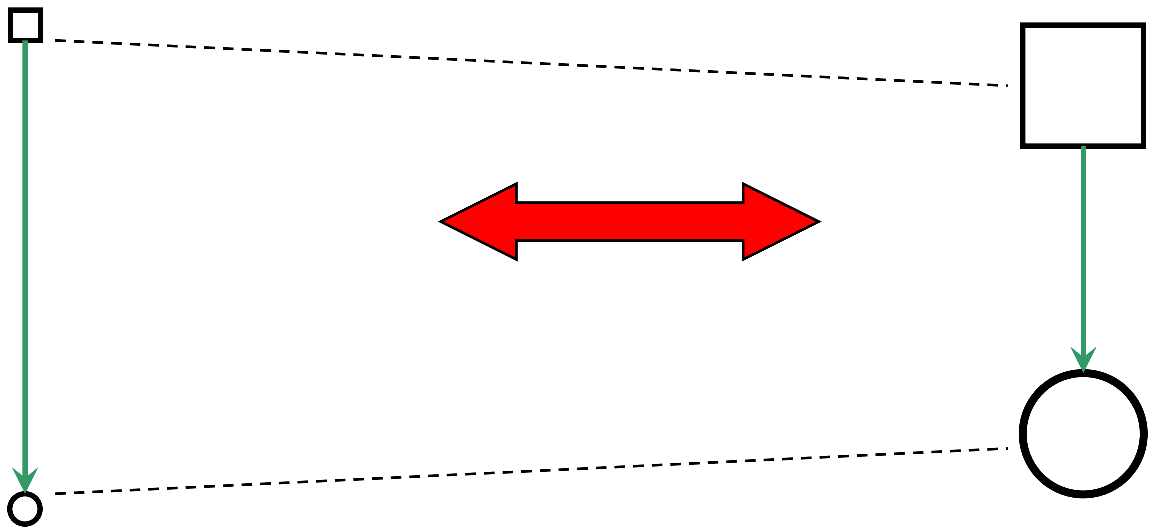

TGG-rule: Connection

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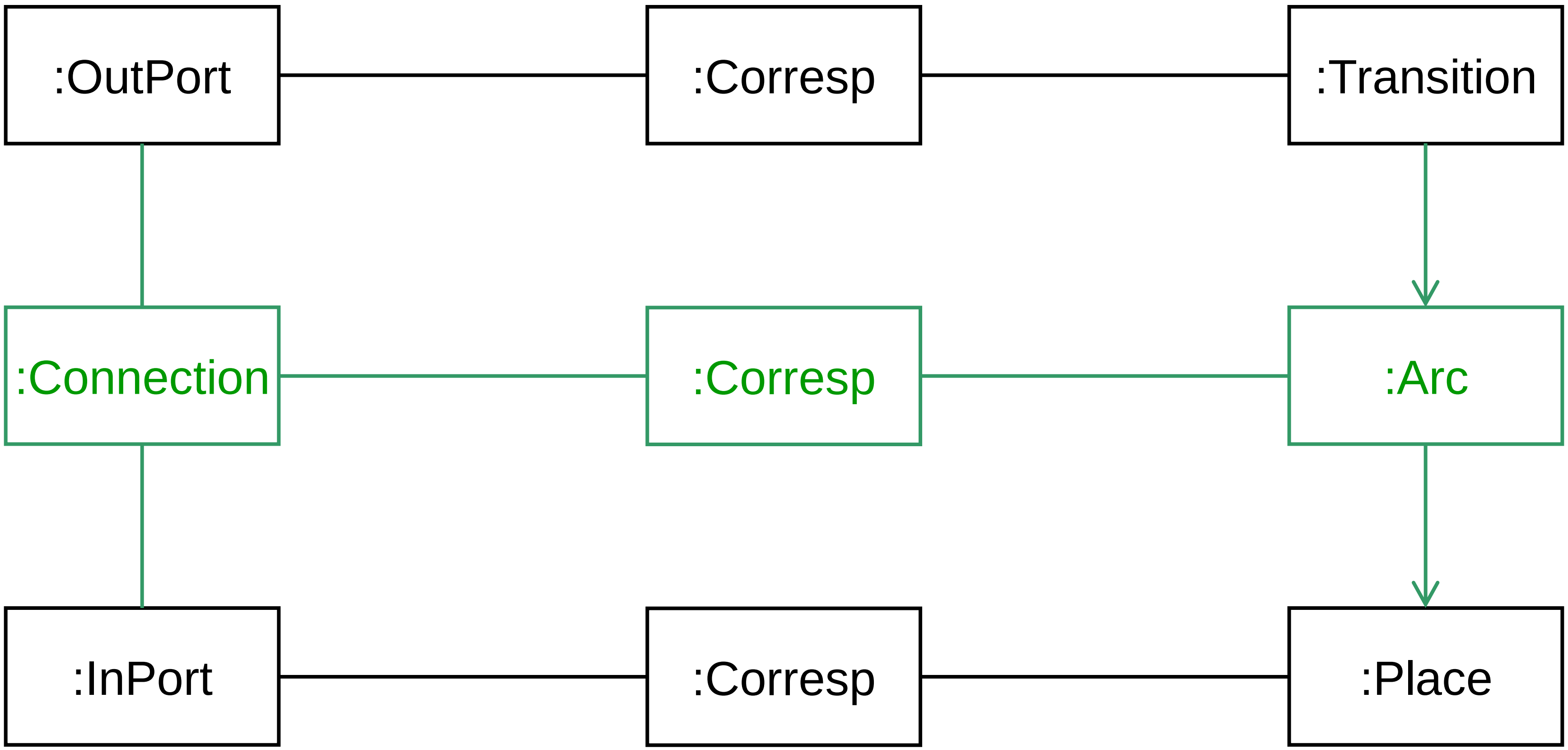
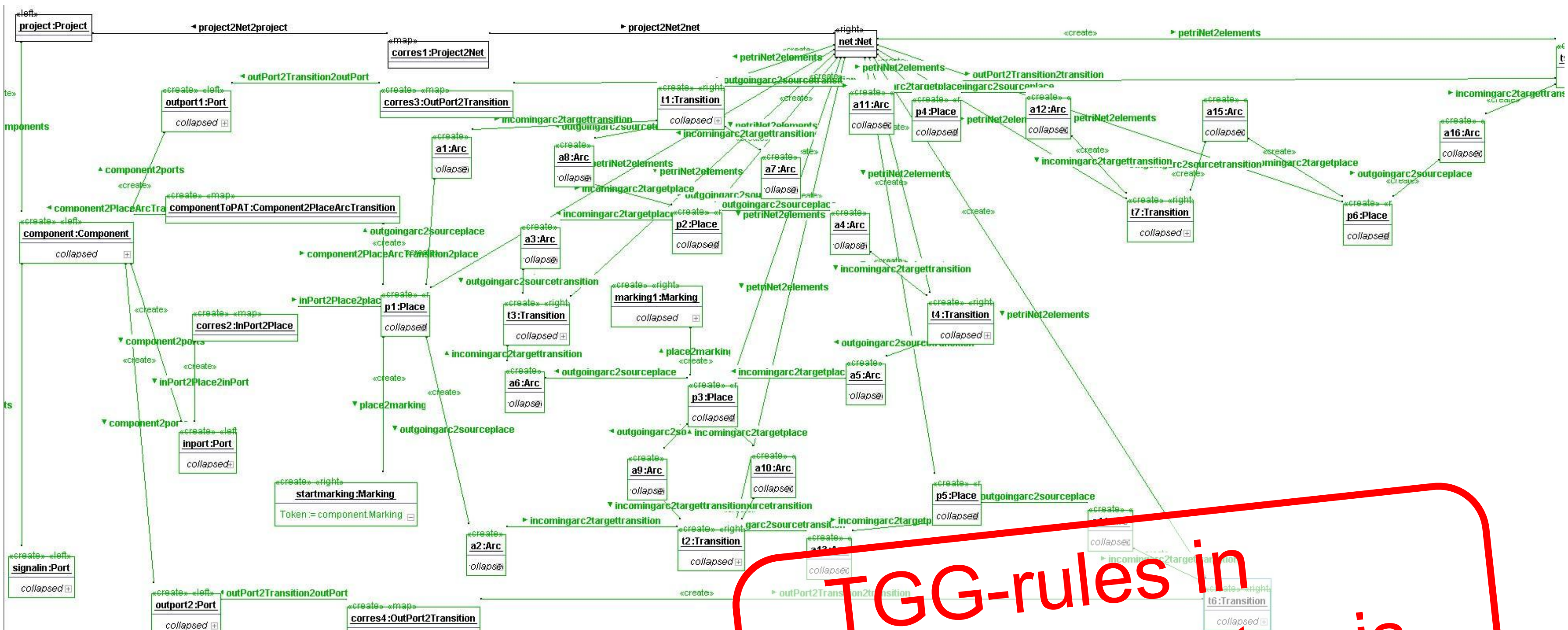


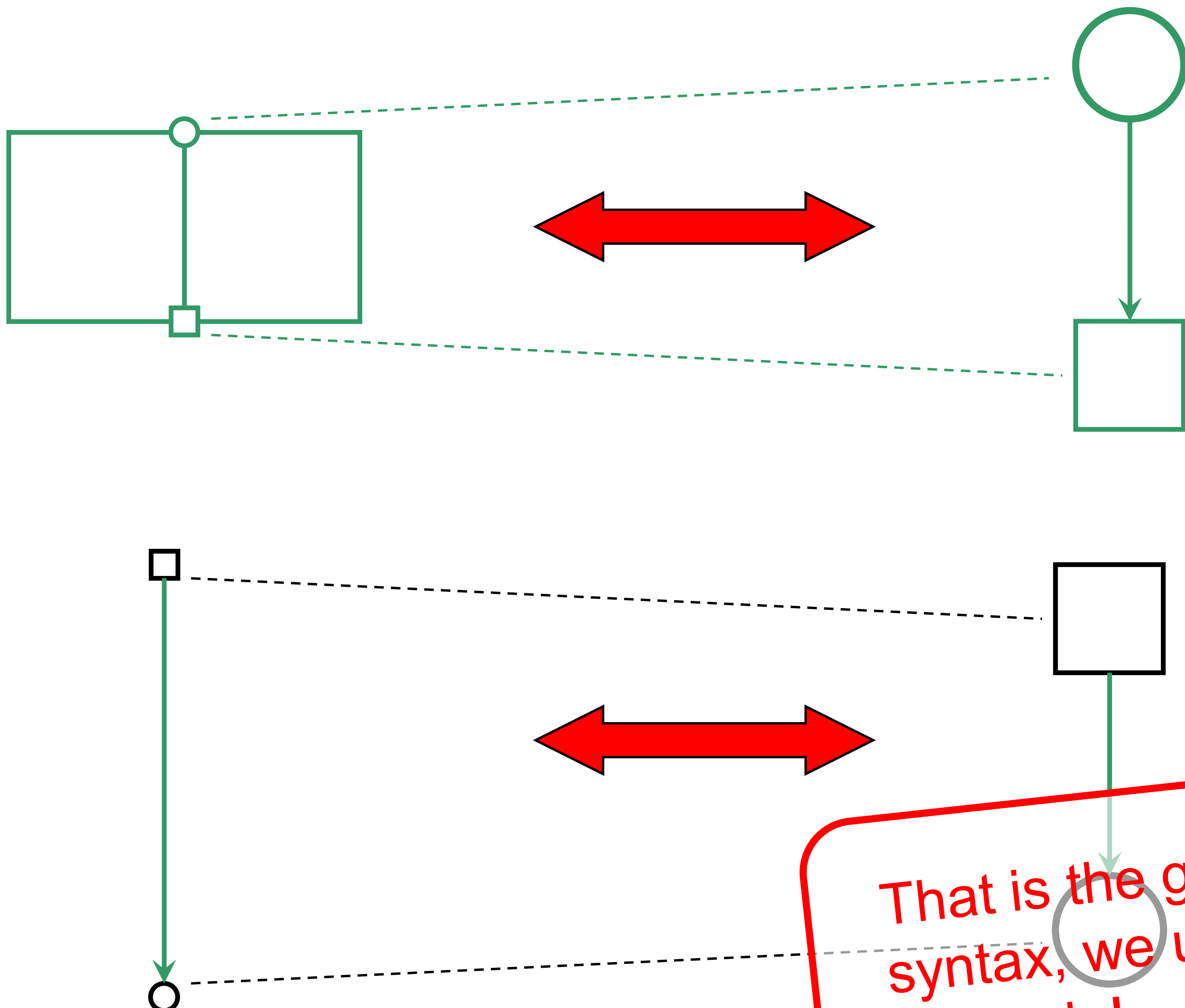
A rule in practice

A real example from component tools.



TGG-rules in abstract syntax is very verbose!

TGG-Rules in “graphical syntax”

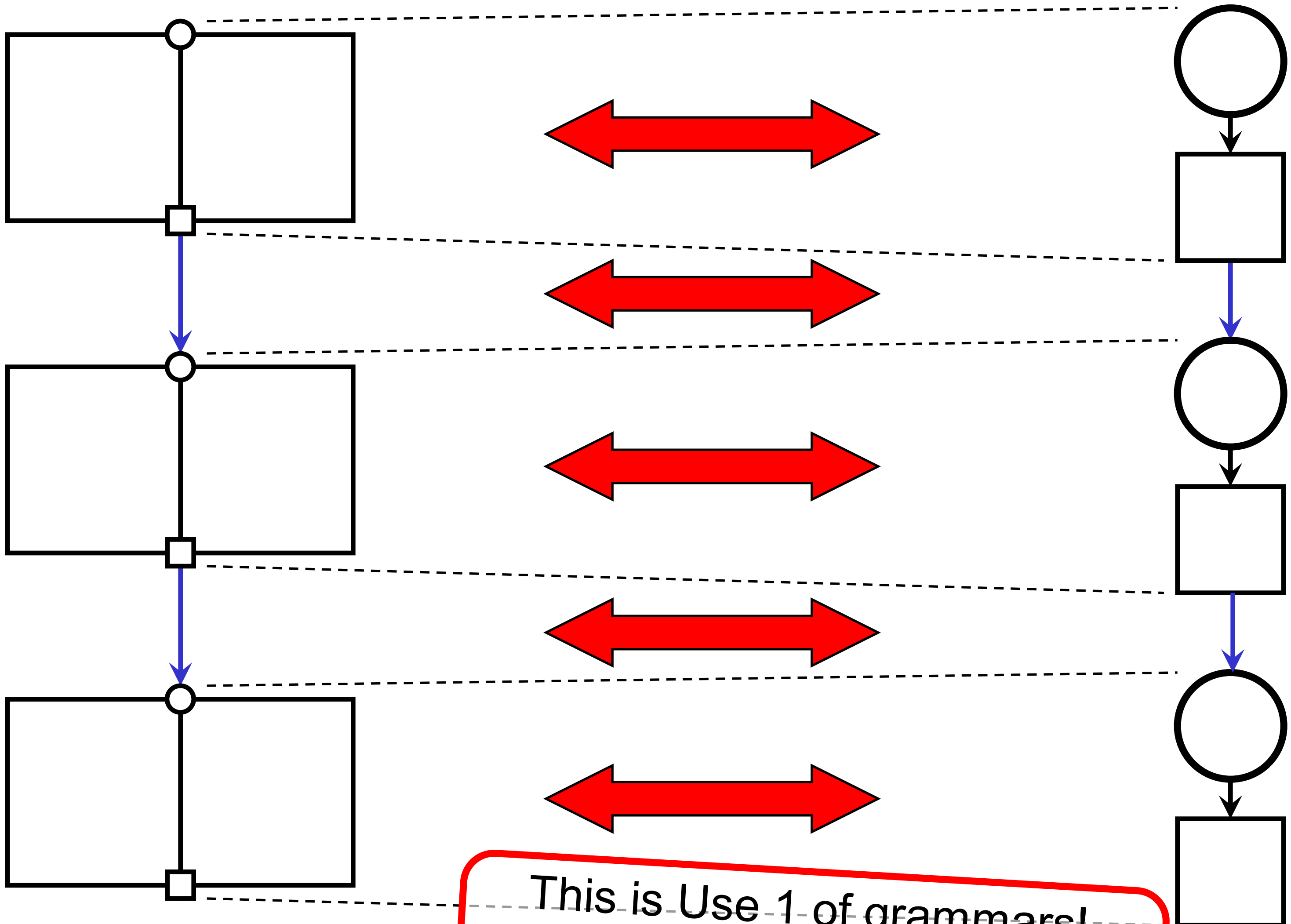


That is the graphical syntax, we used in our example!

Outline

- Example
- Semantics
- Strength
- Problems and Weaknesses
- Extensions and Open Issues

Semantics of TGG-Rules



This is Use 1 of grammars!
Just for two/three models in parallel.

“Model-driven Execution”

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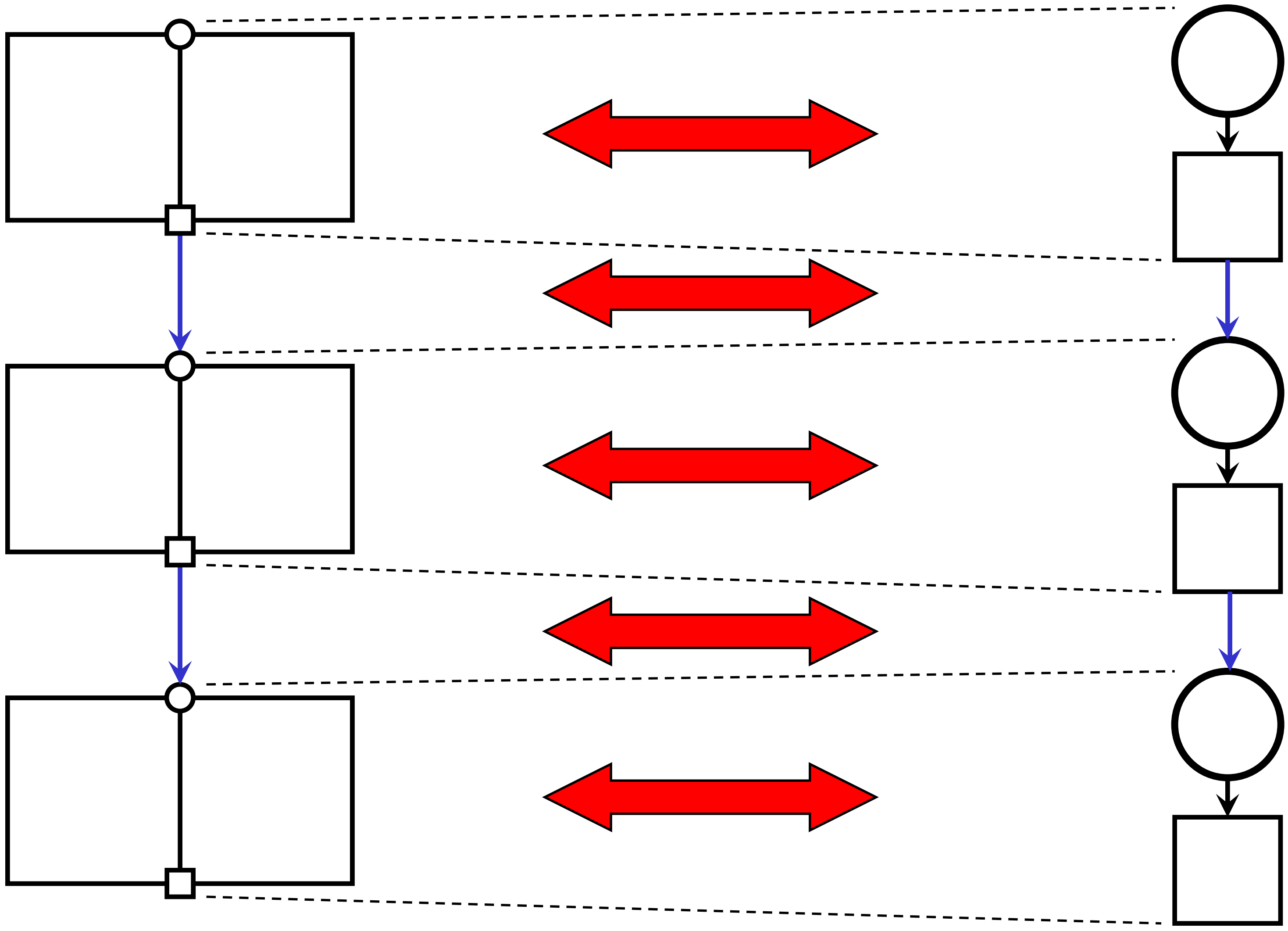

Outline

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Strength of TGGs

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- Rules are declarative and local
- Semantics works both ways

Under some reasonable constraints, which are yet to be identified.

- Yet, the transformations are operational (compiler / interpreter approach)
- Transformations are operational in both directions!

Corollary of locality

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- Transformations can (in principle) be verified for semantical correctness

- Approach works incrementally!

Incremental application

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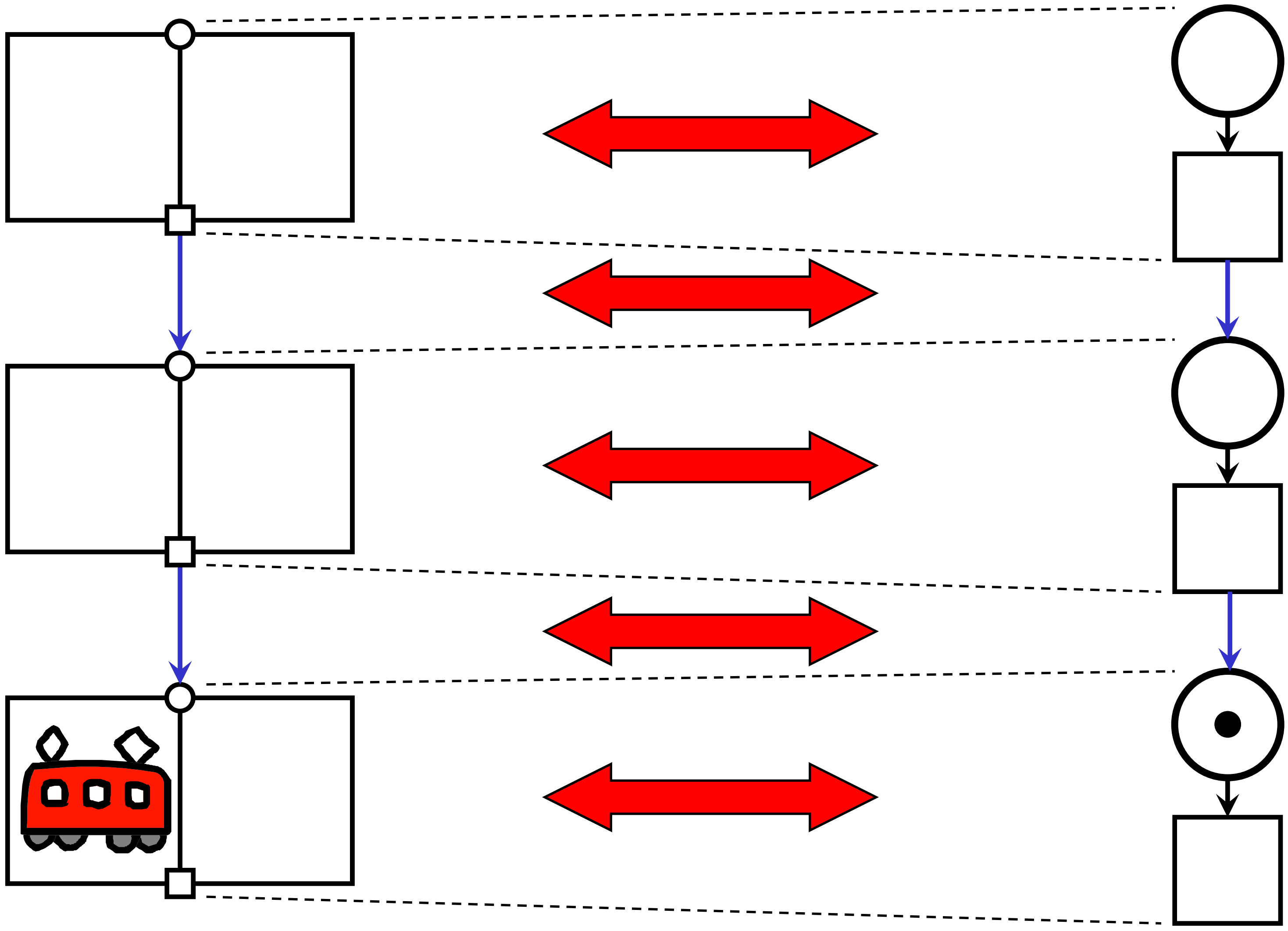

TGGs are good for

- Defining transformations between models that are structurally similar

- Executing these transformations (in models of reasonable size)

TGGs are not so good for

- defining transformations between models that are very different in structure

TGGs should be combined with other transformation technologies such as templates! How?

- defining the legal syntax for the models on each sides of the transformation

Use UML and OCL for defining the legal "syntax" of source and target (meta-modelling).

TGGs are not so good for

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- formulating the rules of real-world examples in abstract syntax

But, this is only a matter of better tool support!
(Could be a nice MSc-project!)

- sometimes there are many large but very similar rules

We need mechanisms for reusing and structuring rules (TGG++):
- “inheritance”
- combination and composition of rules (“where” / “when” → QVT)

Outline

- Example
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Extensions

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- TGG++
  - Inheritance of rules
  - where-clause
  - other “abbreviations”

- Negation

TGG-Rules in “graphical syntax”

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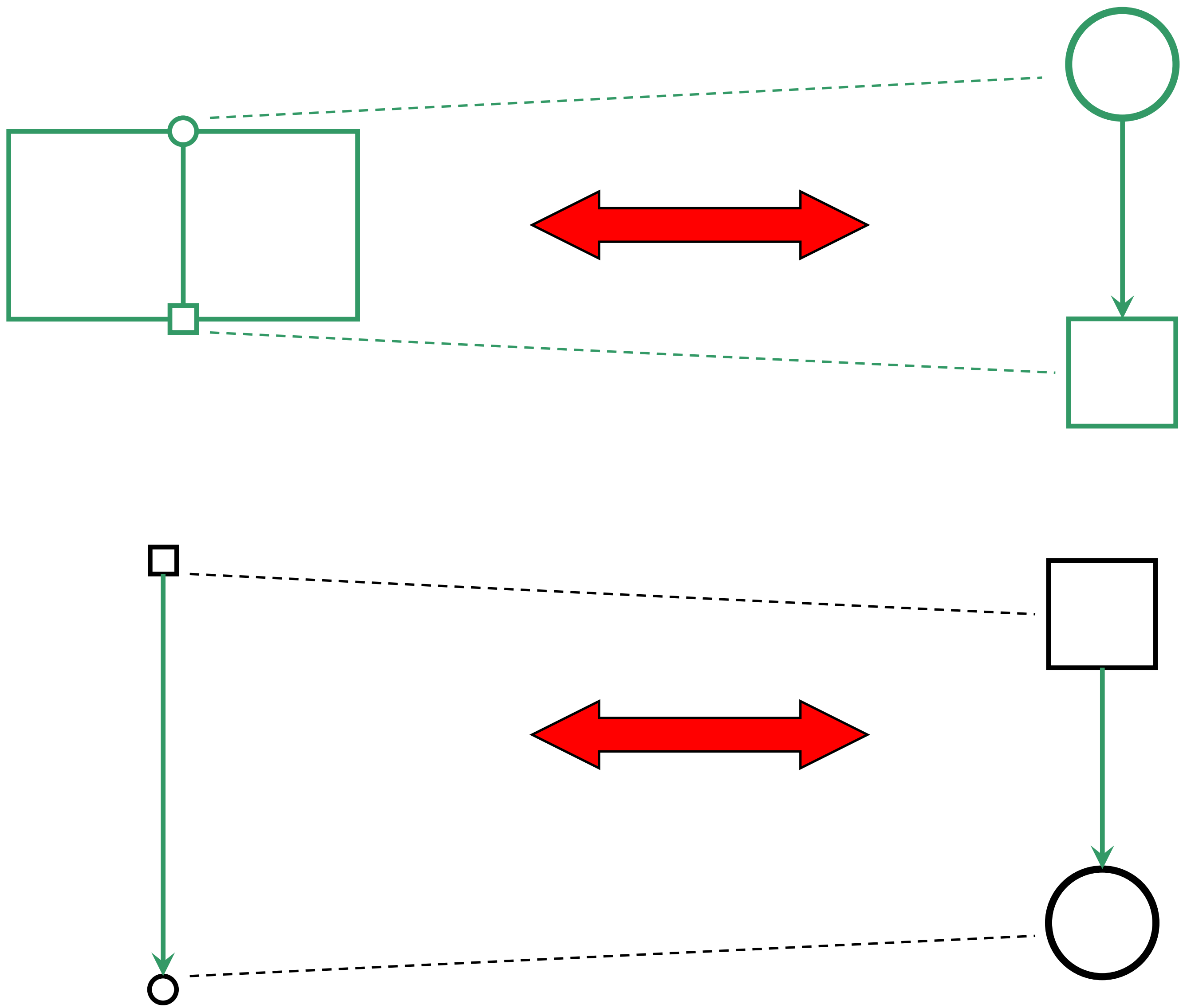

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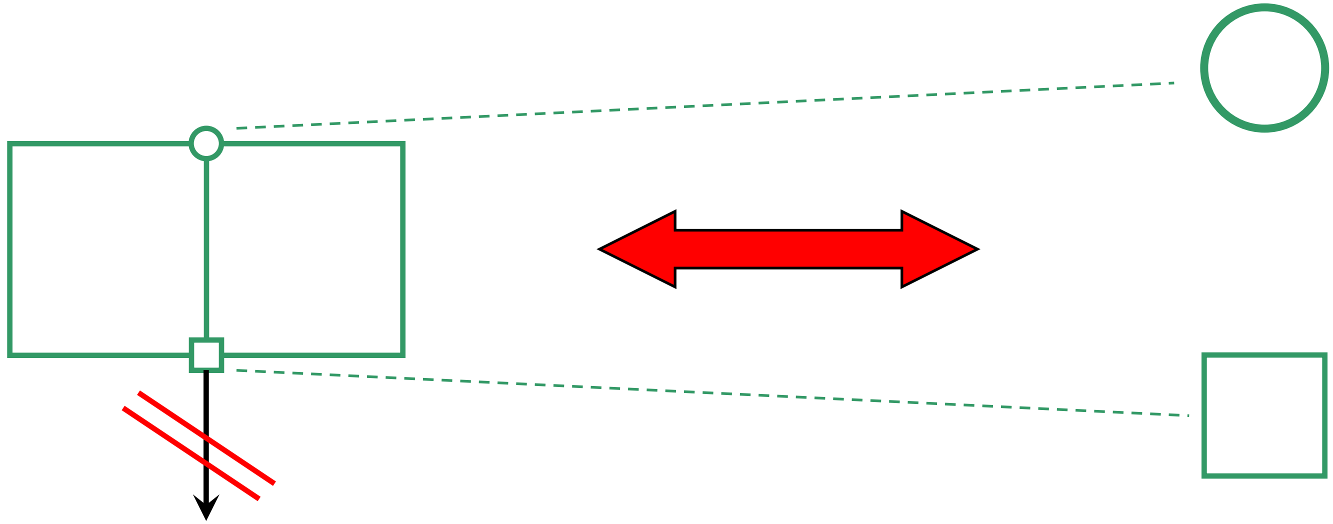

Generation Semantics

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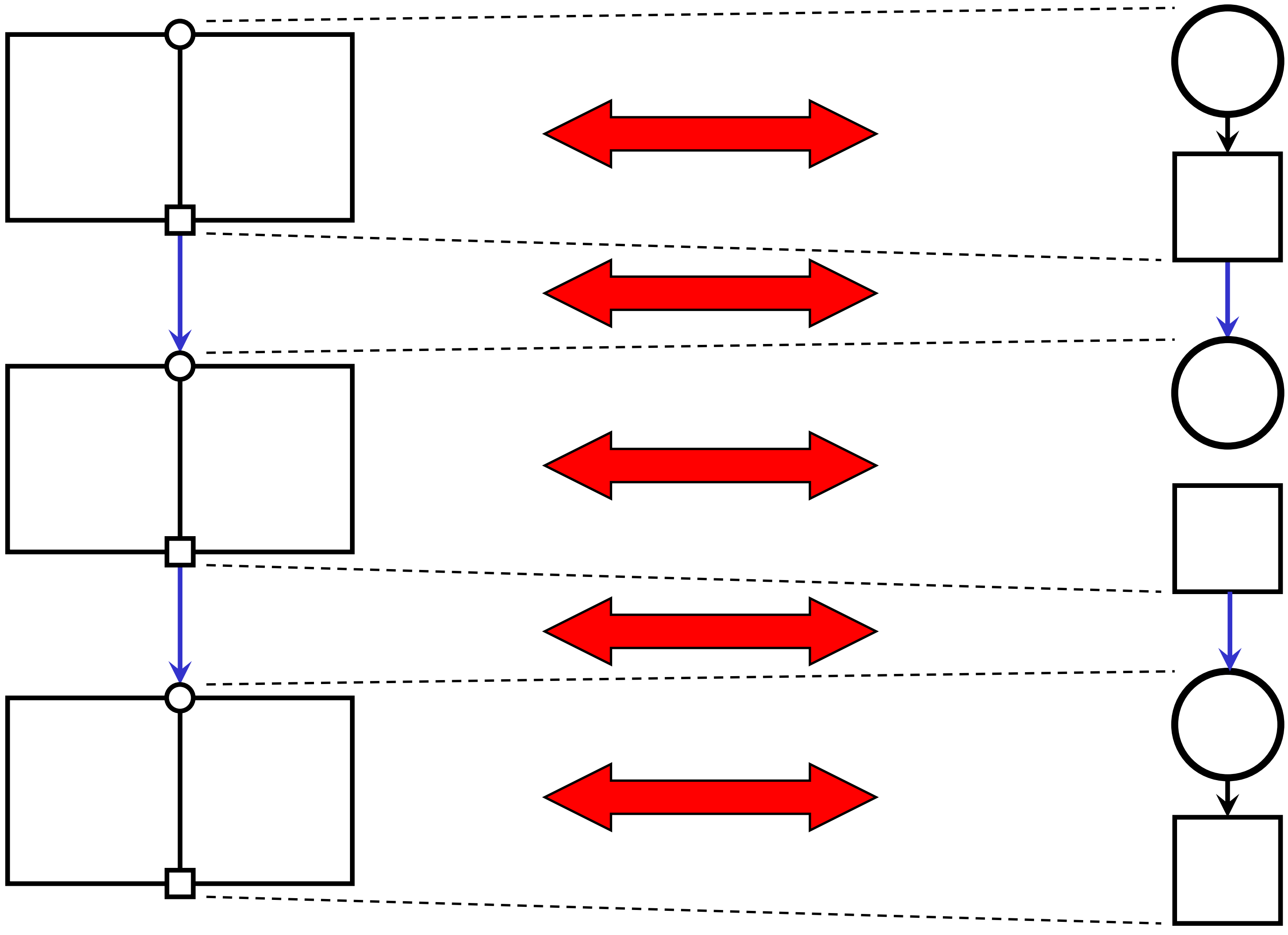
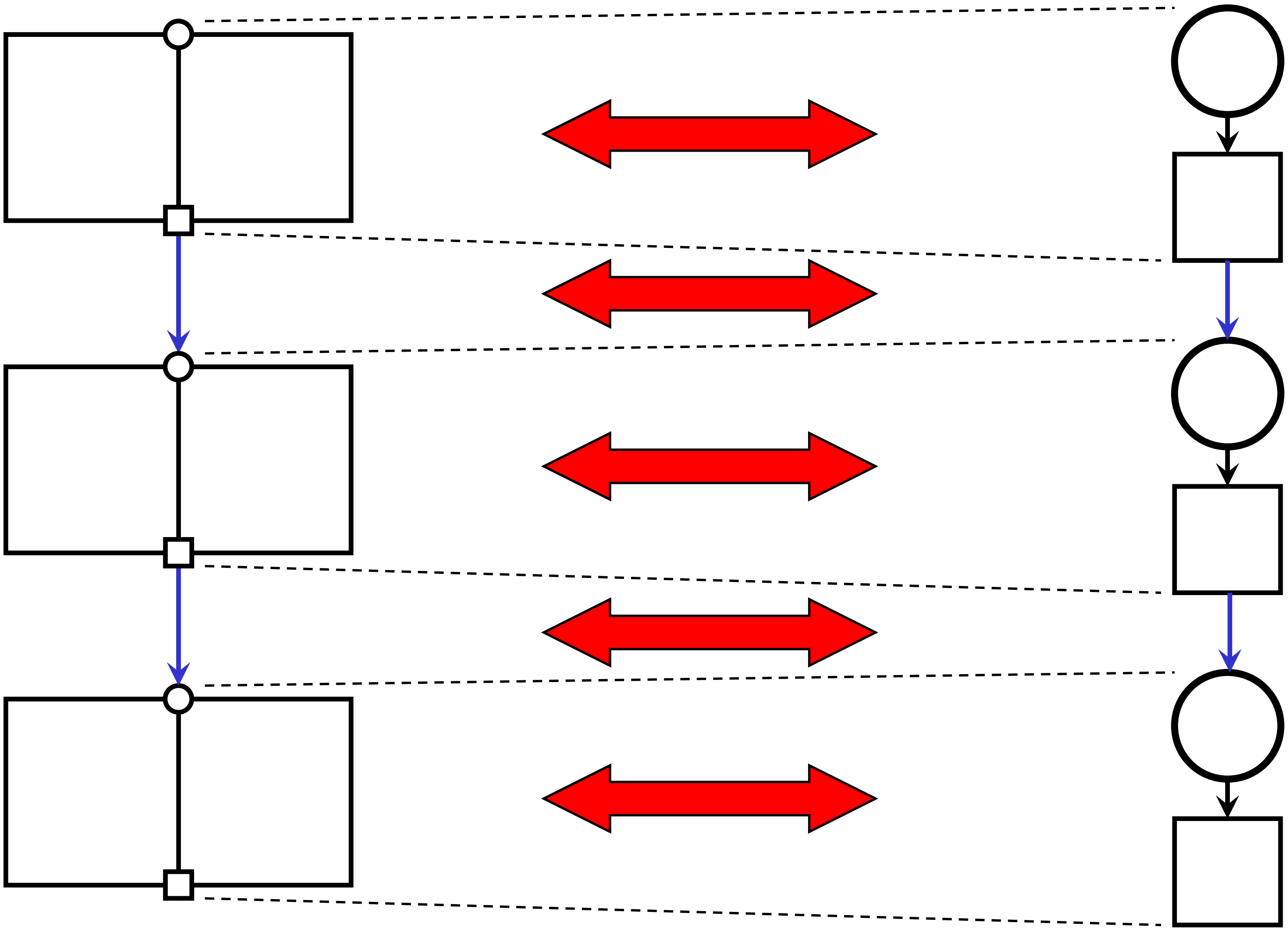


“Model-driven Semantics”



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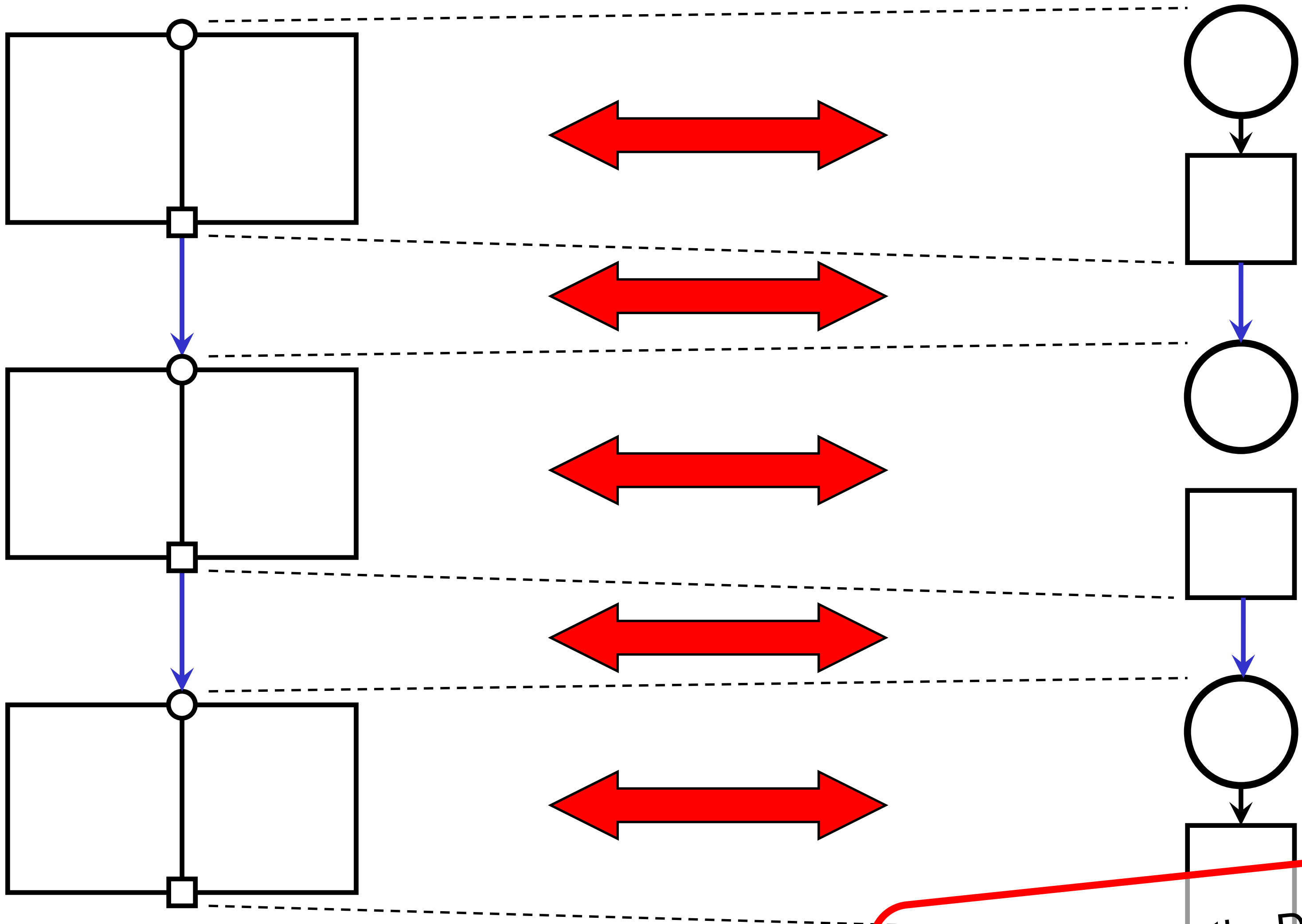


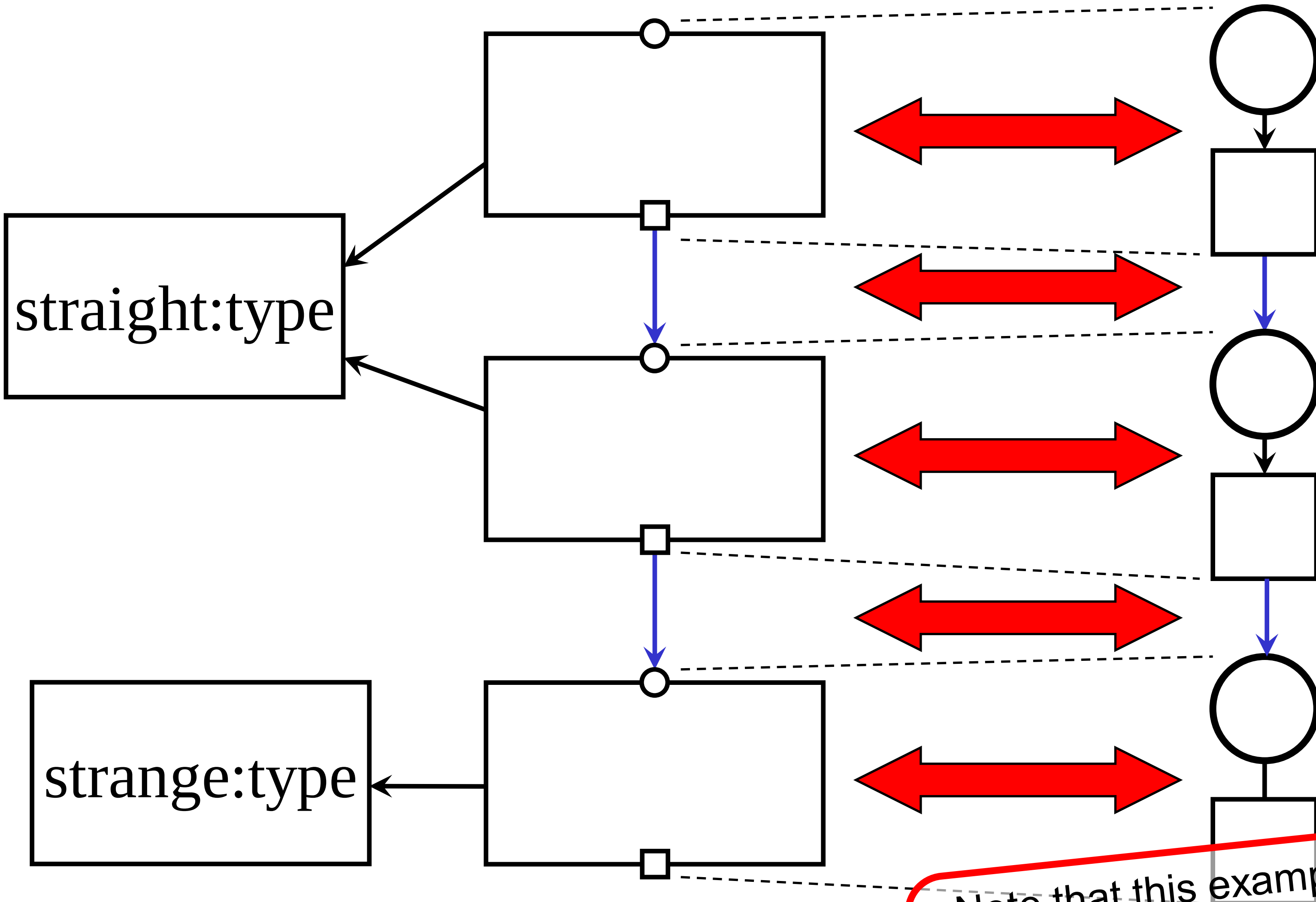
More problematic: Deletion of model elements. But, in principle doable.

Extensions

- TGG++
  - inheritance of rules
  - where-clause
  - other “abbreviations”

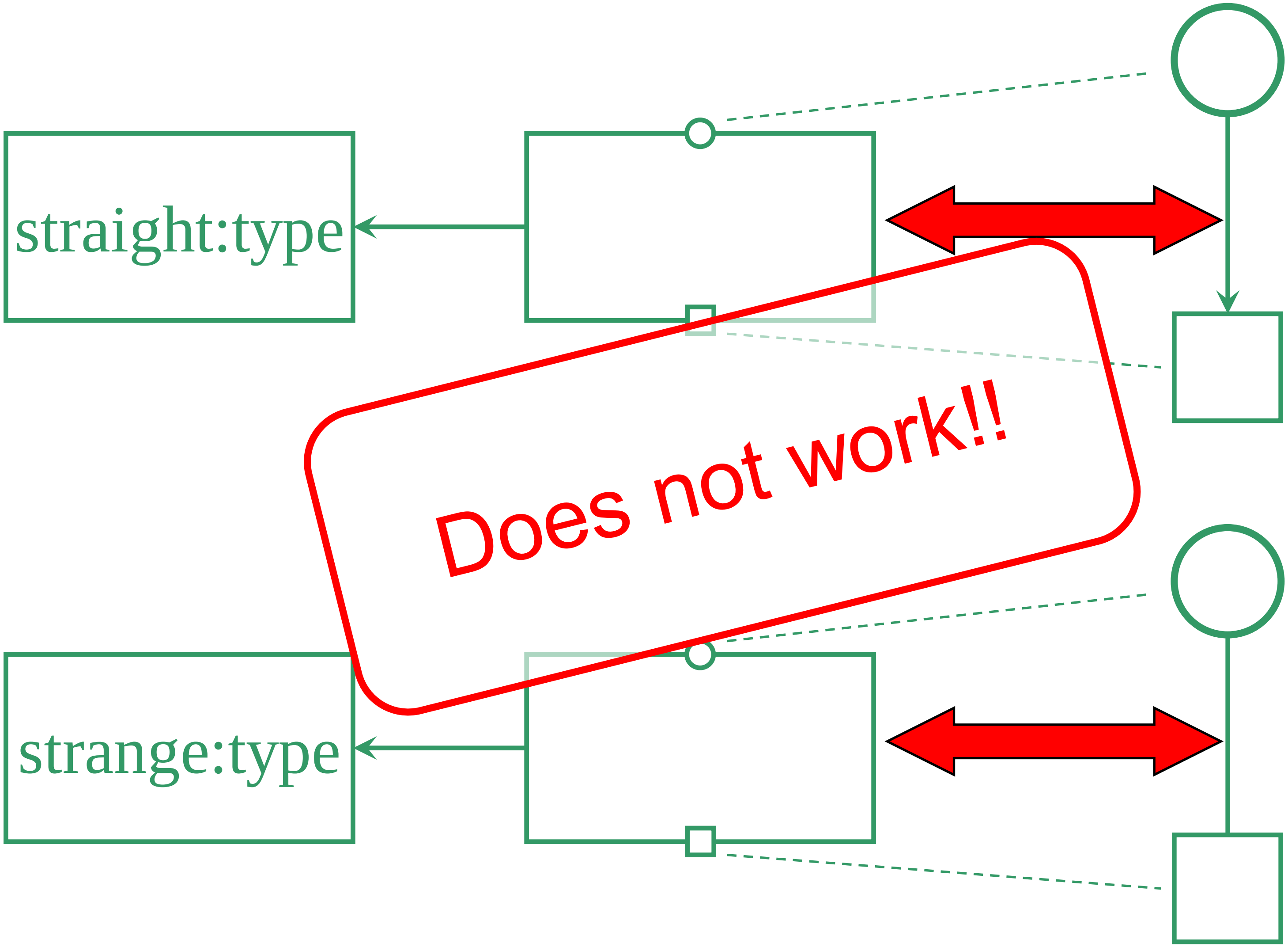
- Negation
  - grammar-style semantics
    (not what we want?)
  - model-driven semantics
    (incrementality lost or incompatible)

Re-usable nodes

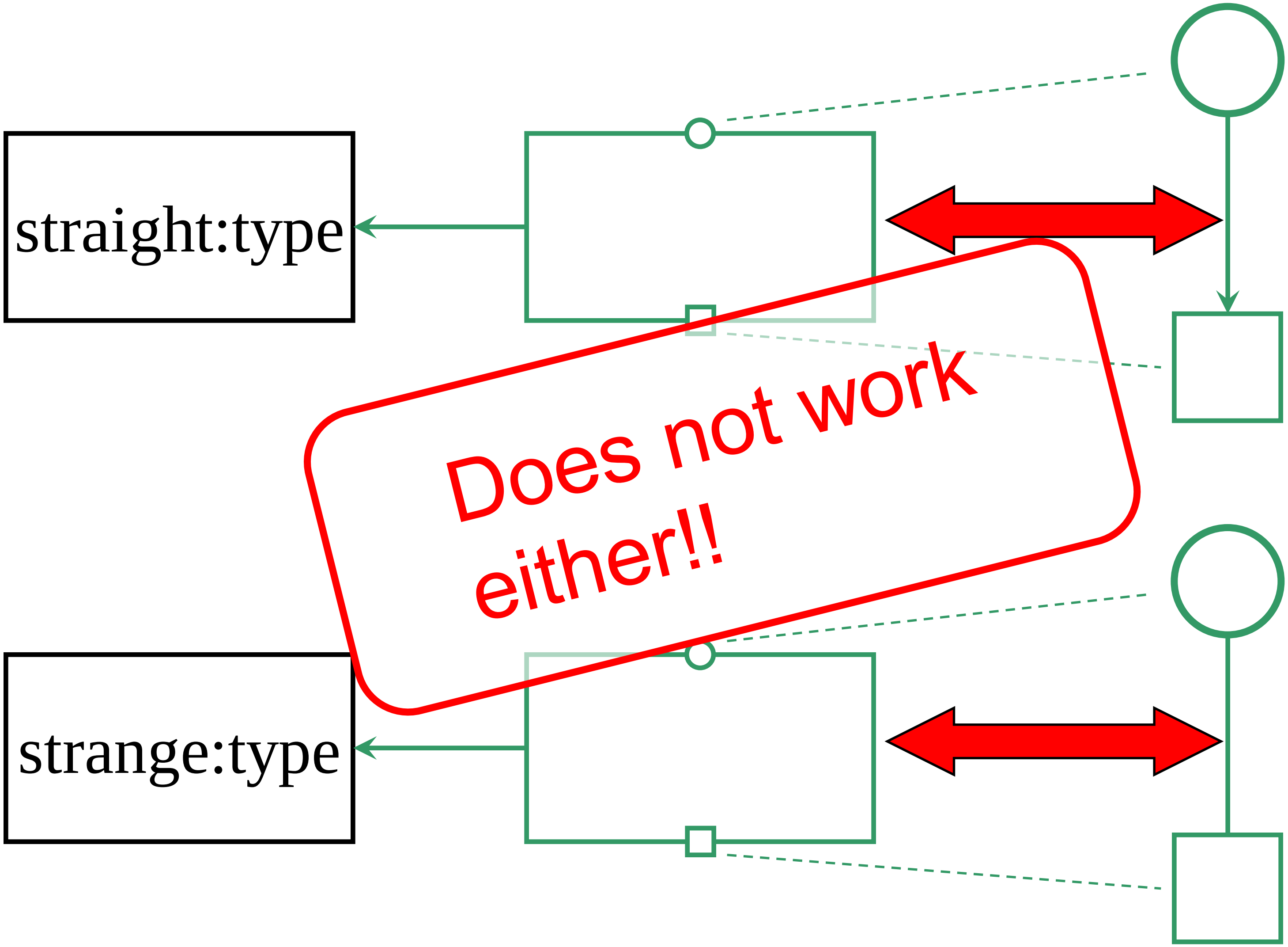


Note that this example uses a changed meta-model (components refer to their type).

Rules?



Rules?



Re-usable nodes

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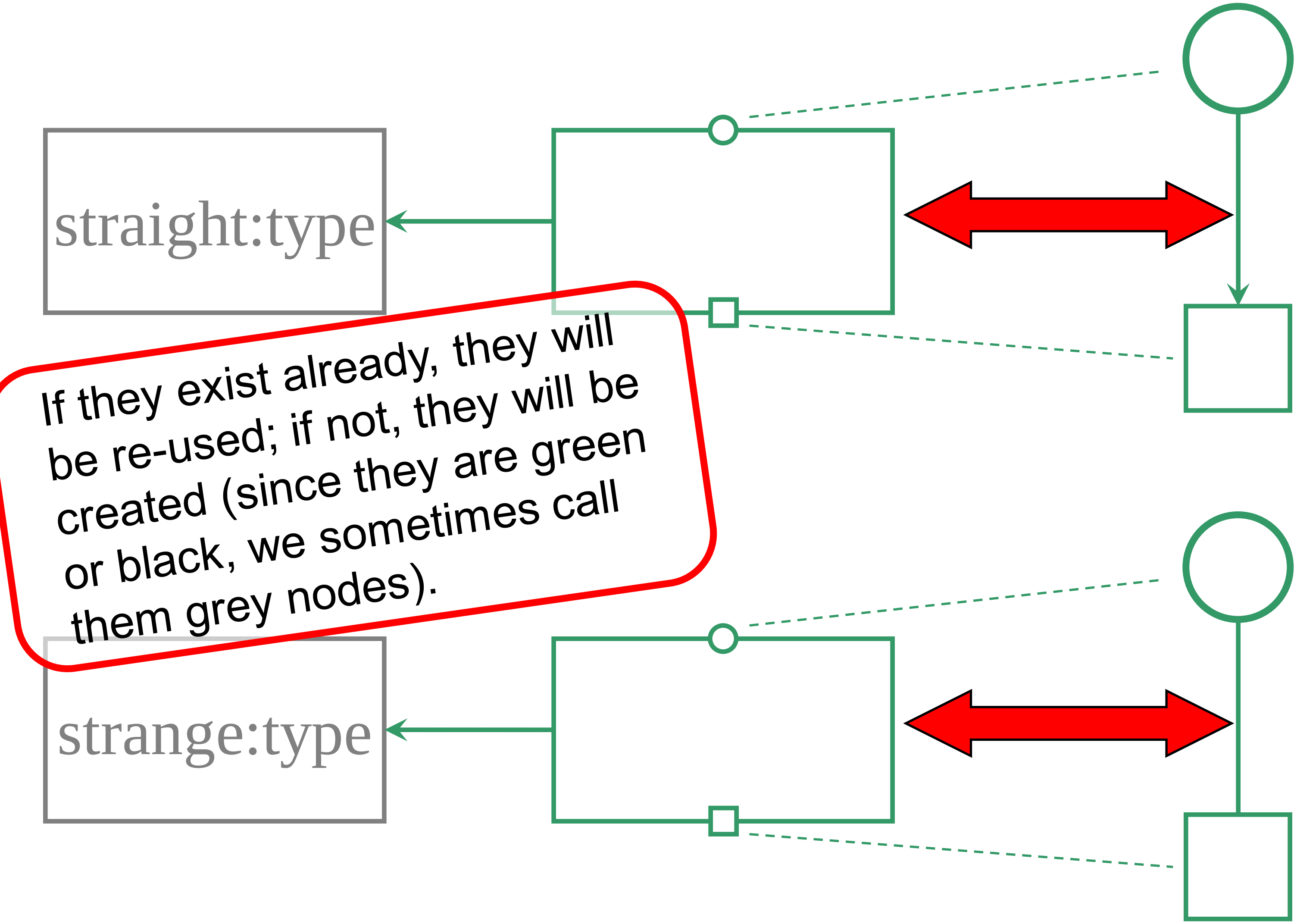


Extensions

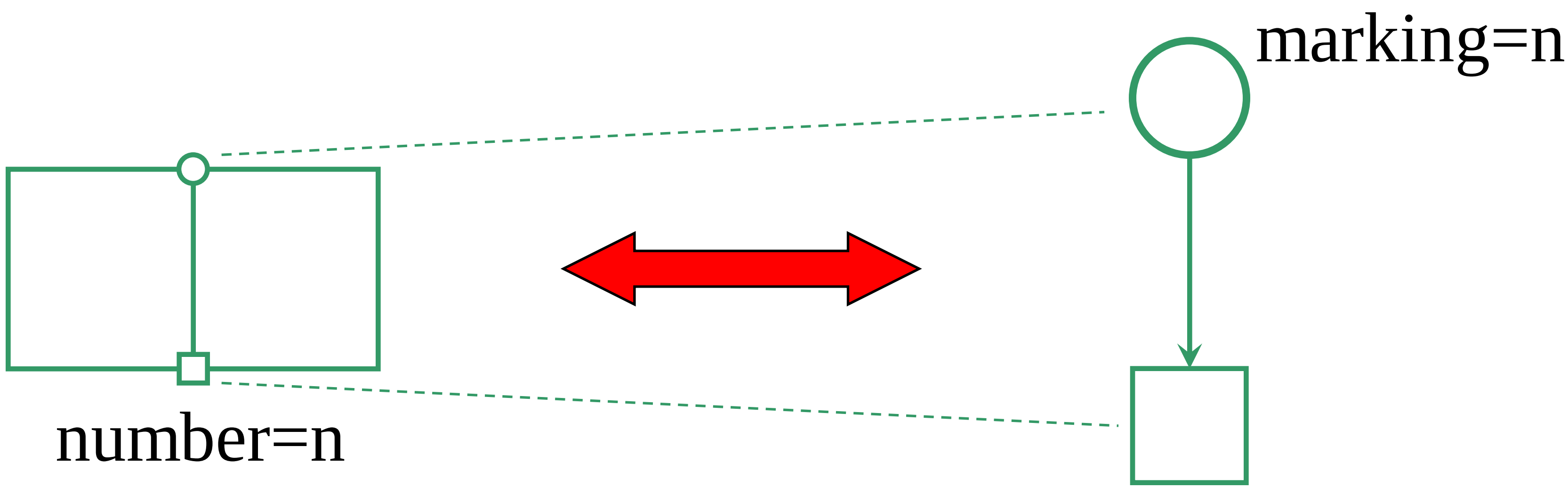
- TGG++
- Negation
- Re-usable nodes (“grey nodes” / ##)

Clean definitions

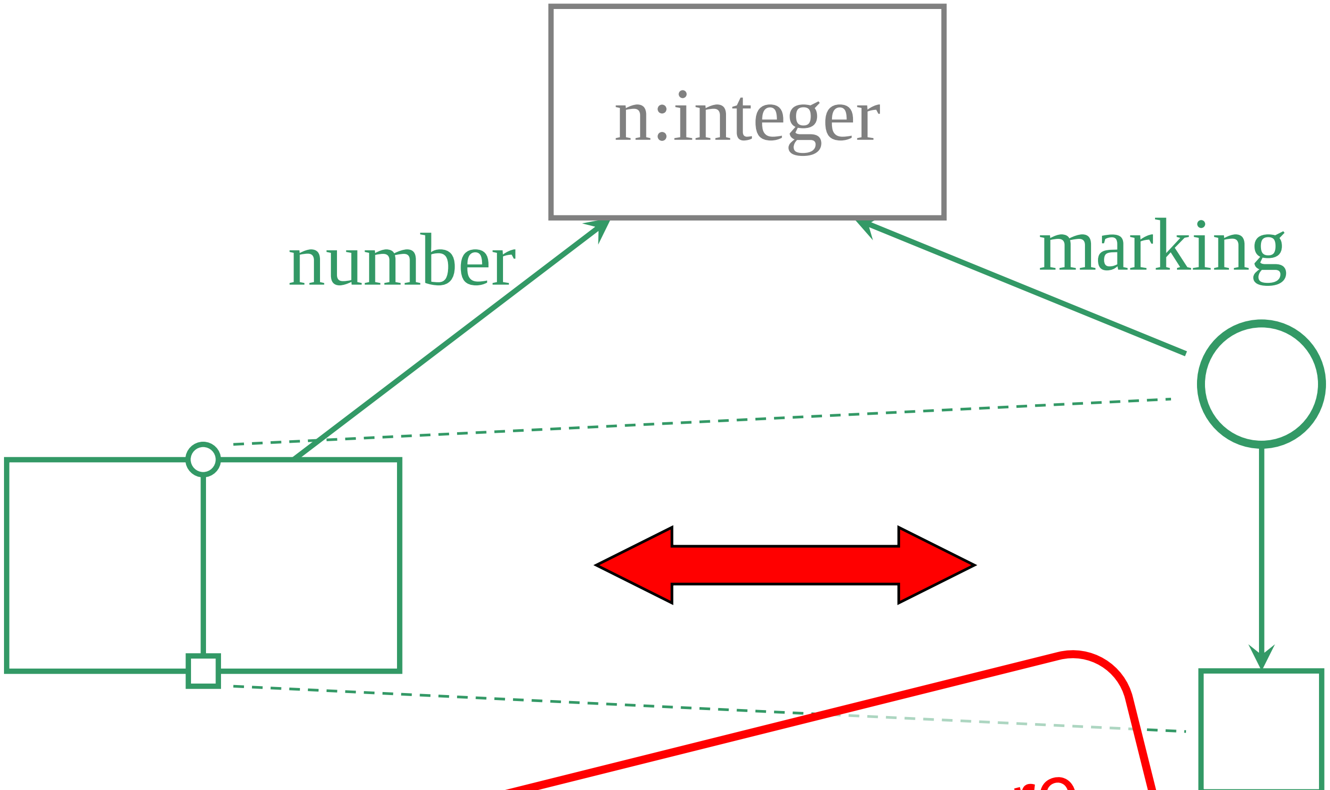
- Attributes

- Inheritance in graph models

Rules in with attributes

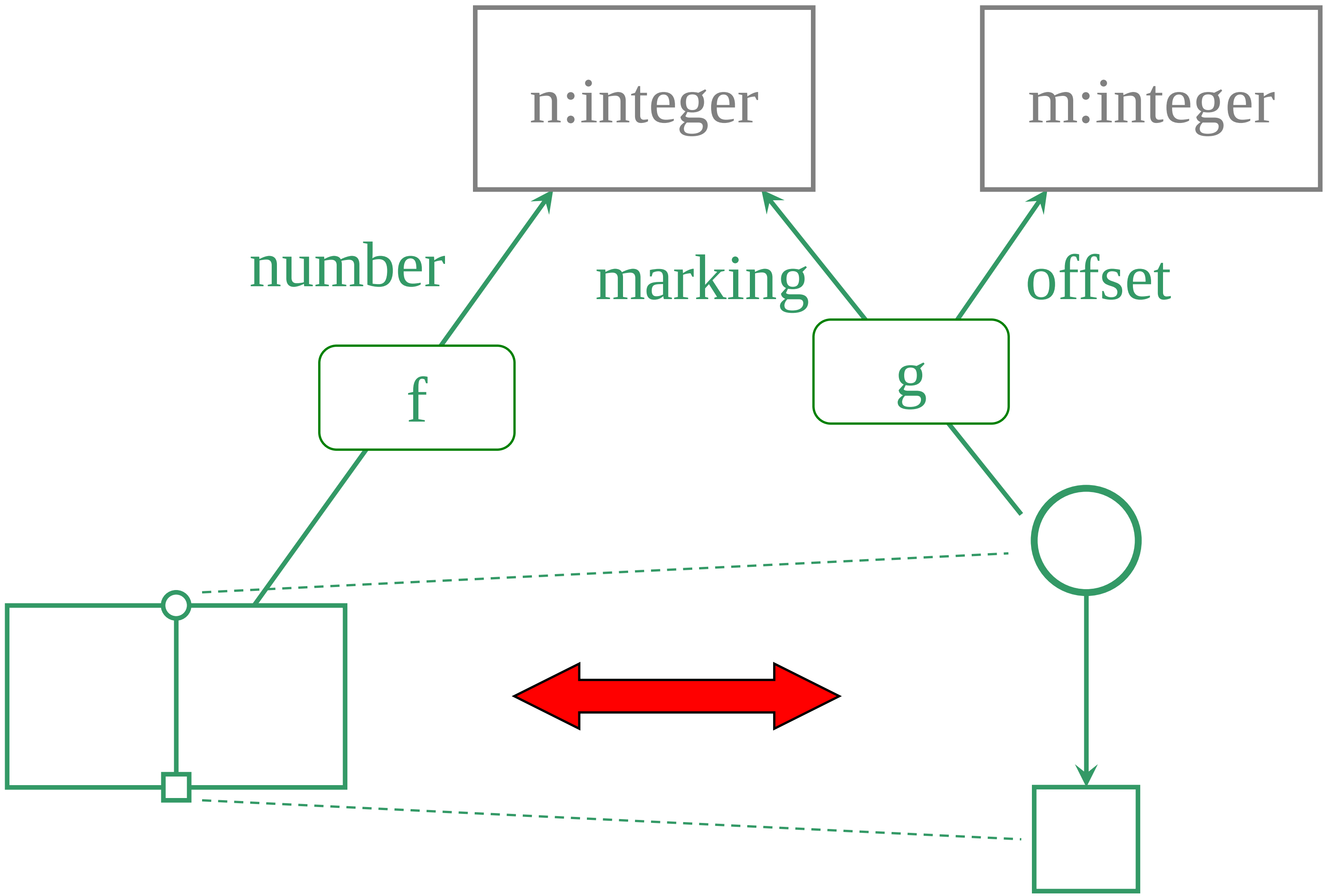


Rules in with attributes



Values of attributes are “grey nodes”!

Attributes: General Concept



Clean definitions

- Attributes
  - are grey nodes
  - problem: operational interpretation needs inverse functions

- Inheritance in graph models

Inheritance

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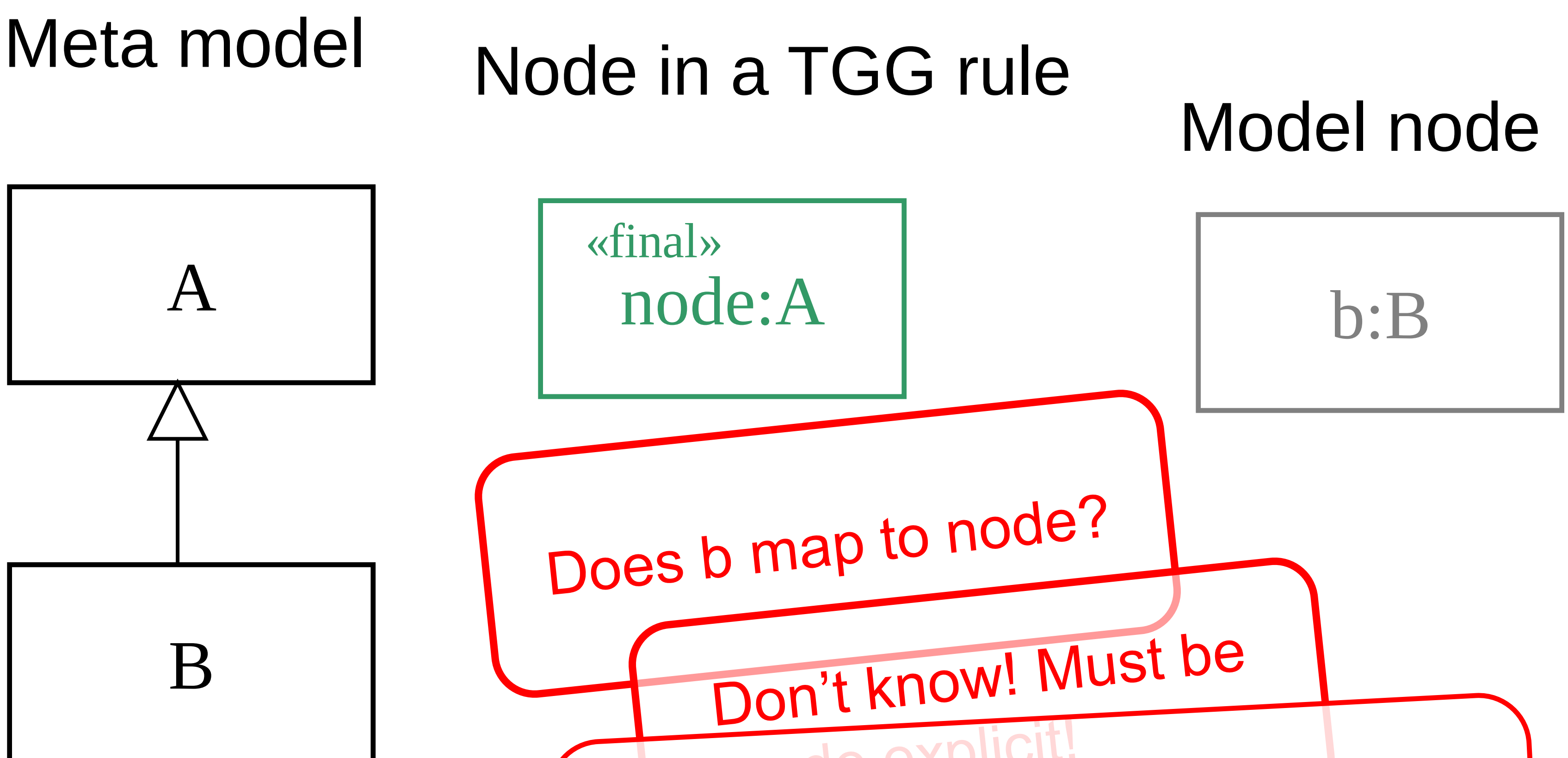

Does b map to node?

Don't know! Must be made explicit!

→ In our tool: the property MatchSubtypes of a node defines, what we want.

Research issues

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- Good examples
- Benchmarks
- "Theory" of sufficient conditions for deterministic transformations /
  deterministic "partial transformations"
- Verification techniques
- Uniform interface / integration of strategies
- Efficient transformations / synchronisation
- …

→ Some of the concepts discussed here, are not implemented in the TGG interpreter we use in our tutorial. Values to attributes are assigned via constraints (see examples in tutorial).

TGGs: Summary

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- (Often) elegant way of defining the relation between two kinds of models
- Based on this definition, models can be
  - transformed in either direction
    (different approaches: compile rules, interprete rules)
  - corresponding models can be kept consistent
    (synchronization)
- Good for defining the relation between structurally similar models

TGGs: Literature

1. A. Schürr. *Specification of graph translators with triple graph grammars*. In E. W. Mayr, G. Schmidt, and G. Tinhofer, editors, Graph-Theoretic Concepts in Computer Science, 20th International Workshop, WG '94, Springer LNCS 903, 151-163, June 1994.

2. E. Kindler, R. Wagner: *Triple Graph Grammars: Concepts, Extensions, Implementations, and Application Scenarios*. Technical Report, Department of Computer Science, University of Paderborn, tr-ri-07-284, June 2007.

→ We did NOT invent TGGs (that was Andy Schürr more than 20 years ago)

→ Due to their nice concepts we are enthusiastic about them anyway and try to promote them.