Model-Based Software Engineering

Lecture 07 – Introduction to Semantics, Transformation, Execution, Analysis

Prof. Dr. Joel Greenyer

May 31, 2016

Acknowledgment

- The slides of this lecture are inspired by lecture slides from
  - *Ekkart Kindler*: Course on Advanced Topics in Software Engineering, DTU Compute, 2015.
    - http://www2.imm.dtu.dk/courses/02265/f15/schedule.shtml
  - *Ina Schäfer, Christoph Seidl*: Modellbasierte Software-entwicklung, TU Braunschweig, 2015.
  - *Steffen Becker*: Model-Driven Software Development, Universität Paderborn, 2013
  - The Eclipse Open Model CourseWare (OMCW) Project:
    - https://eclipse.org/gmt/omcw/

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5.1. Introduction to semantics, transformations, execution, analysis

Leibniz Universität Hannover

Previously

- In the previous lectures, we covered several aspects of defining a formal language (possibly domain specific)
  - Metamodeling
    - including OCL
  - Defining a concrete syntax
    - graphical
    - textual

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Formal Language

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- ...what do I do with it?

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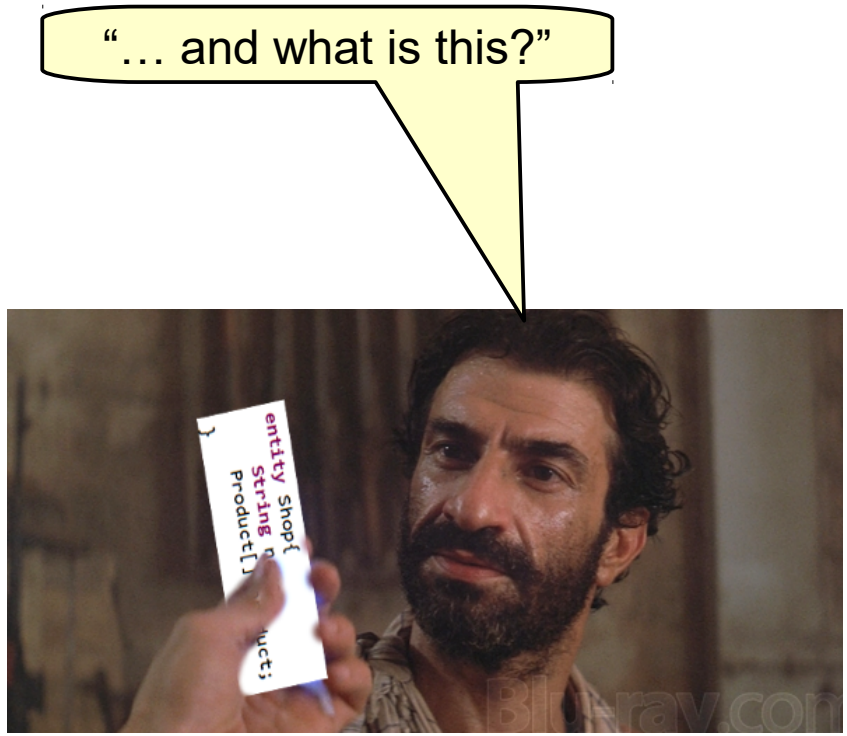

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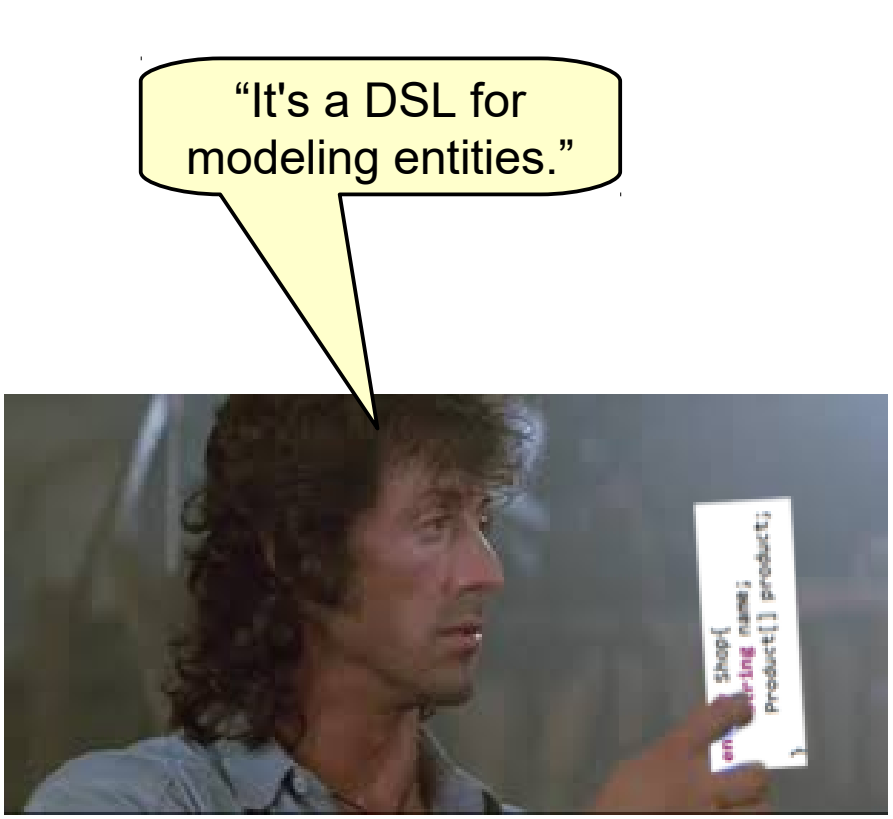

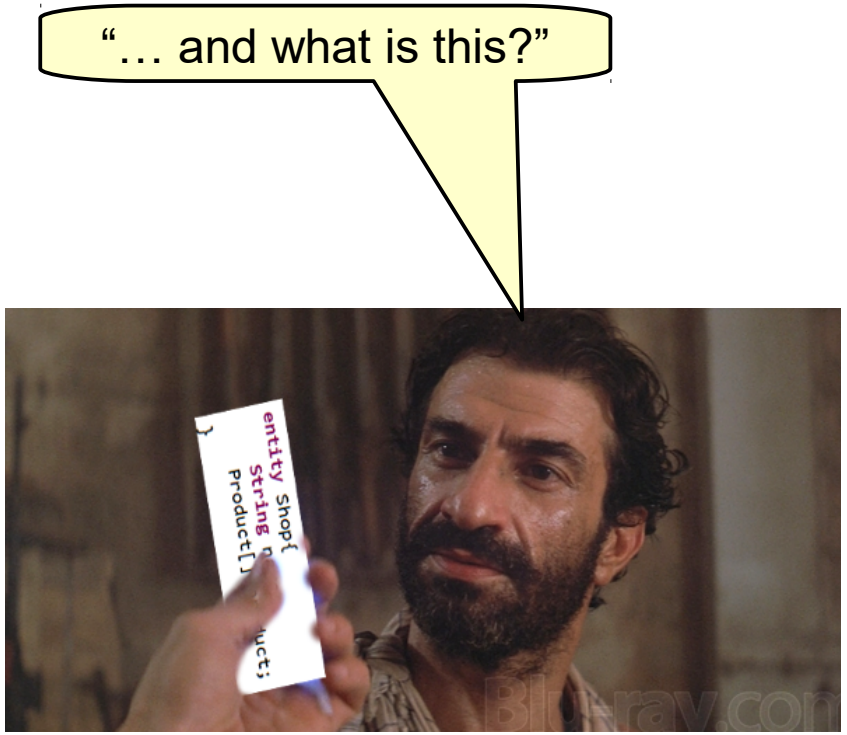

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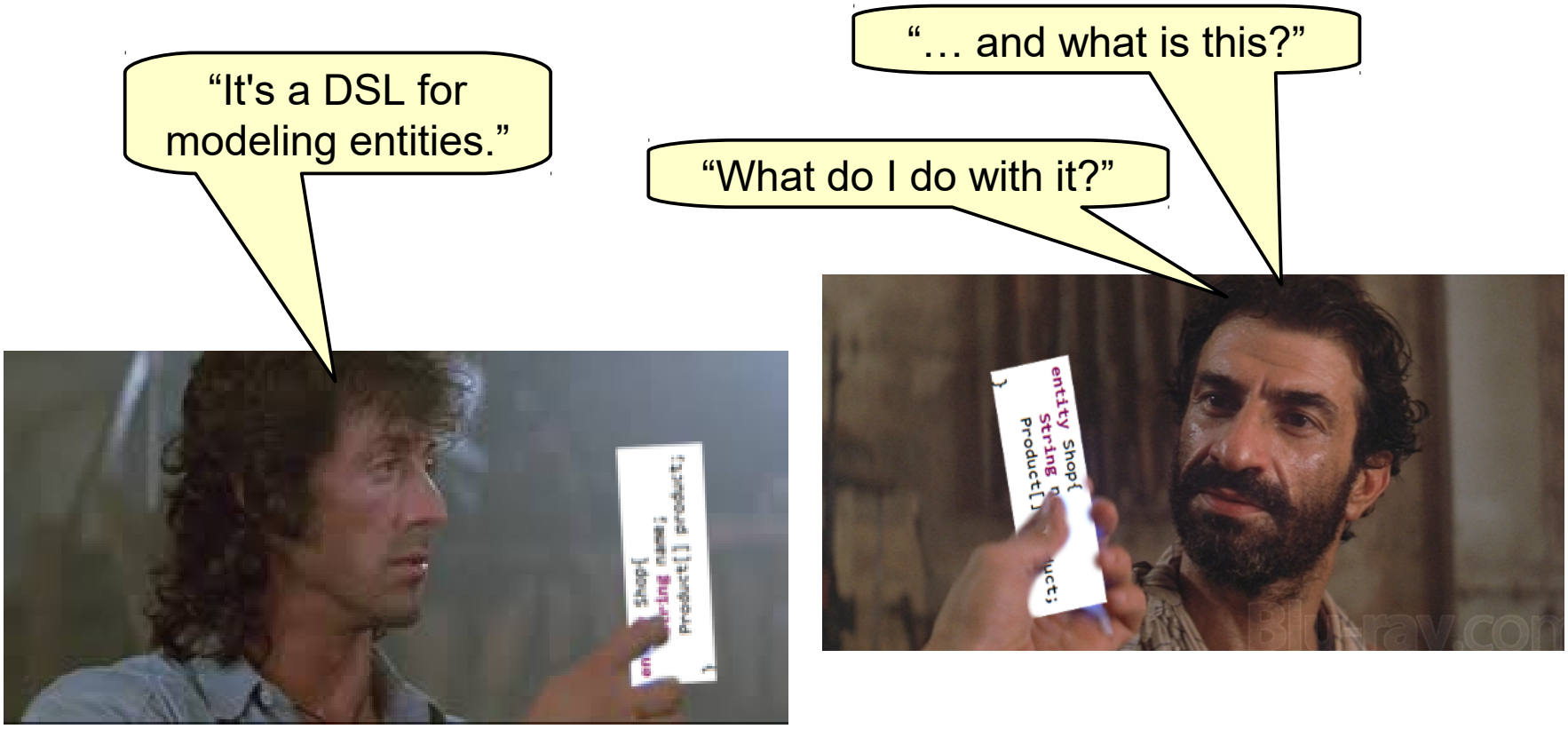

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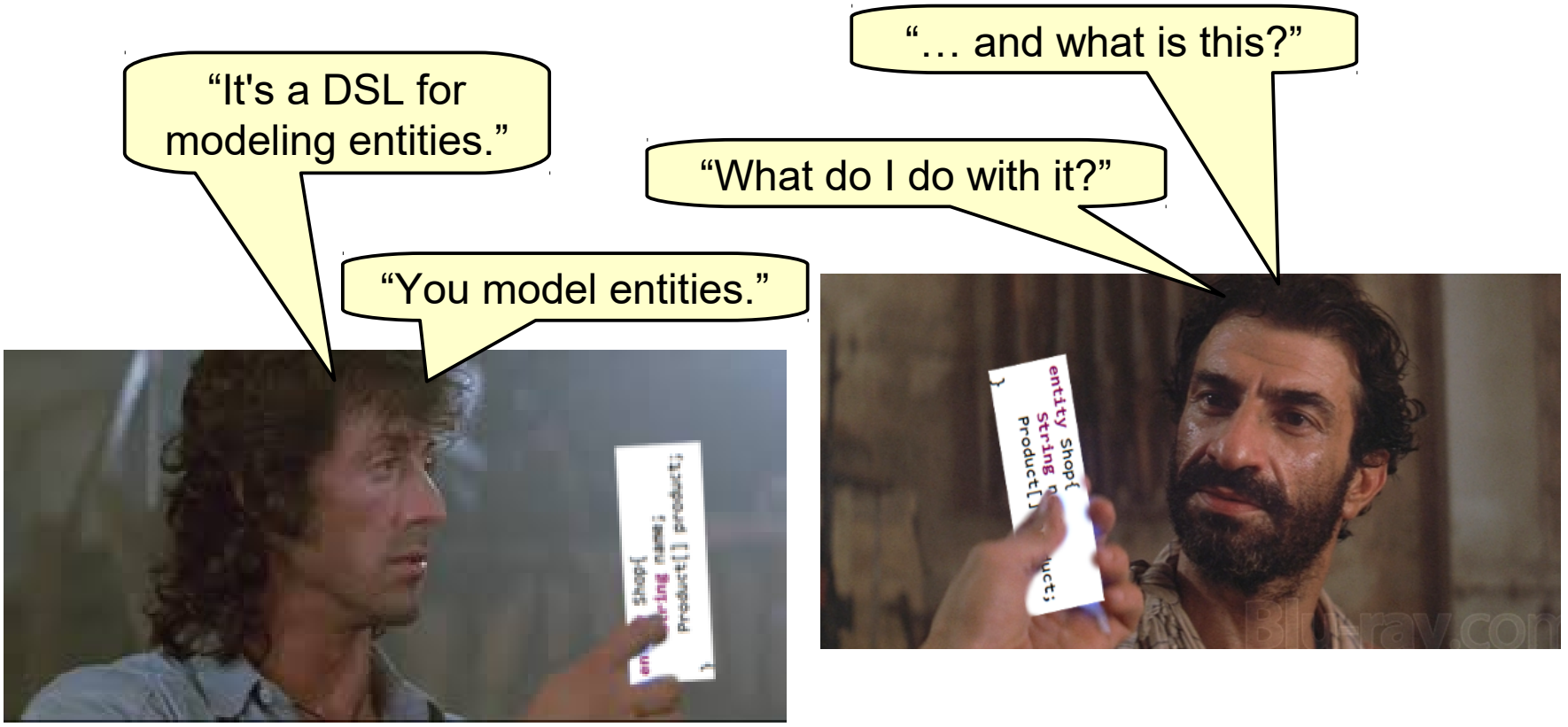

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SOFTWARE ENGINEERING

Formal Language

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    - performance, dependability, formal checks, …
- In order to do these things, we need to define the meaning of our formal language---its **semantics**

Formal Language

- (see Lecture 2)

- A **formal language definition** contains the definition of
  - the **abstract syntax**: defines its internal structure
    - Defines the language constructs and how they can be combined
  - the **concrete syntax**: defines its **notation,** its visual representation for the user (textual or graphical)
  - the **semantics**: defines the meaning of the language constructs and their combinations
  - (sometimes also) the **serialization syntax**: how are sentences of the language stored or exchanged by tools

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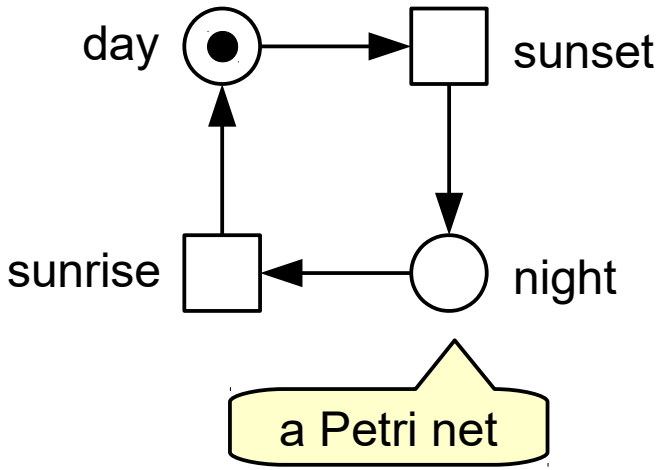
What is the Semantics of these Models?

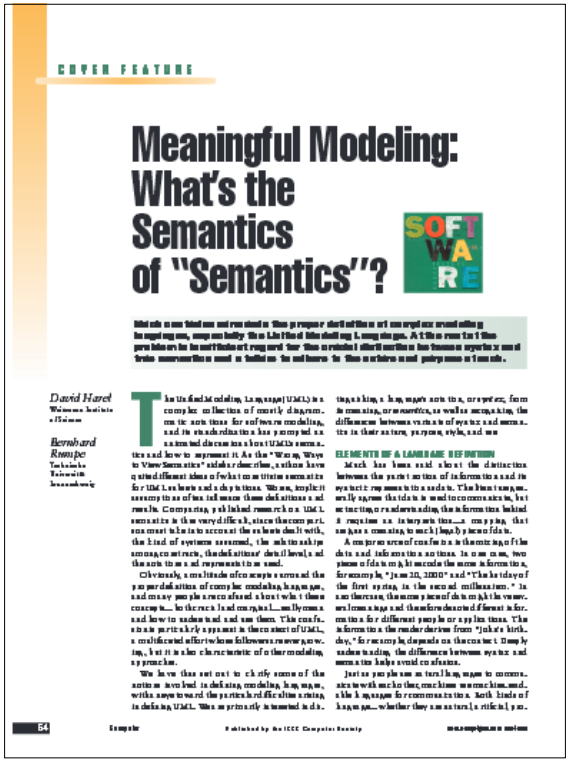
```
entity Shop{
        String name;
        Product[] product;
}

entity Product{
        String name;
        Int productNumber;
}

entity Book extends Product{
        String ISBN;
        String publisher;
}

entity CD extends Product{
        String label;
}
```

an 'Entities' model



What's the Semantics of Semantics?

- D. Harel and B. Rumpe, "Meaningful modeling: what's the semantics of "semantics"?," in Computer, vol. 37, no. 10, pp. 64-72, Oct. 2004.
  - http://www.wisdom.weizmann.ac.il/~harel/papers/ModSemantics.pdf



COVER FEATURE

Meaningful Modeling: What's the Semantics of "Semantics"?

SOFTWARE

David Harel
Weizmann Institute of Science

Bernhard Rumpe
Technische Universität Braunschweig

Wrong Ways to View Semantics

(from "Meaningful modeling: what's the semantics of "semantics"?")

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  - required to describe the semantics, but not semantics itself

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  - *Semantic Domain*: Another language or logic that can be used to describe the semantics of a language

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  - *Semantic Domain*: Another language or logic that can be used to describe the semantics of a language
  - But to name a semantic domain alone is not enough
  - it is required to describe a **detailed mapping** of how the constructs of your language correspond to concepts in the semantic domain

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  - Their semantics does not relate to the behavior of a system
  - Thus, semantics and behavior should not be confused

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    - probably true

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      - example (relates, but subtle difference):
        - » One semantics of finite state automata describes all possible sequences in which transitions can fire (all possible executions)
        - » Another semantics defines which transition fires next in a given current state, and what the current state will be in the next step

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- **"Semantics means looking mathematical"**
  - "When some people see that parts of a language definition have mathematical symbols, they are convinced that it is probably also precisely defined. This is simply not true."

Wrong Ways to View Semantics

(from "Meaningful modeling: what's the semantics of "semantics"?")

- **"Semantics is _____"**
  - Some people simply give a buzzword to indicate something about how the semantic definition goes, as in "the semantics is given by message-passing". This prompts others to think that the language is properly endowed with semantics. Sadly, the worst cases are when the people making this kind of statement actually believe it themselves."

Ways to Define Semantics?

- How do we define the semantics of a formal language?

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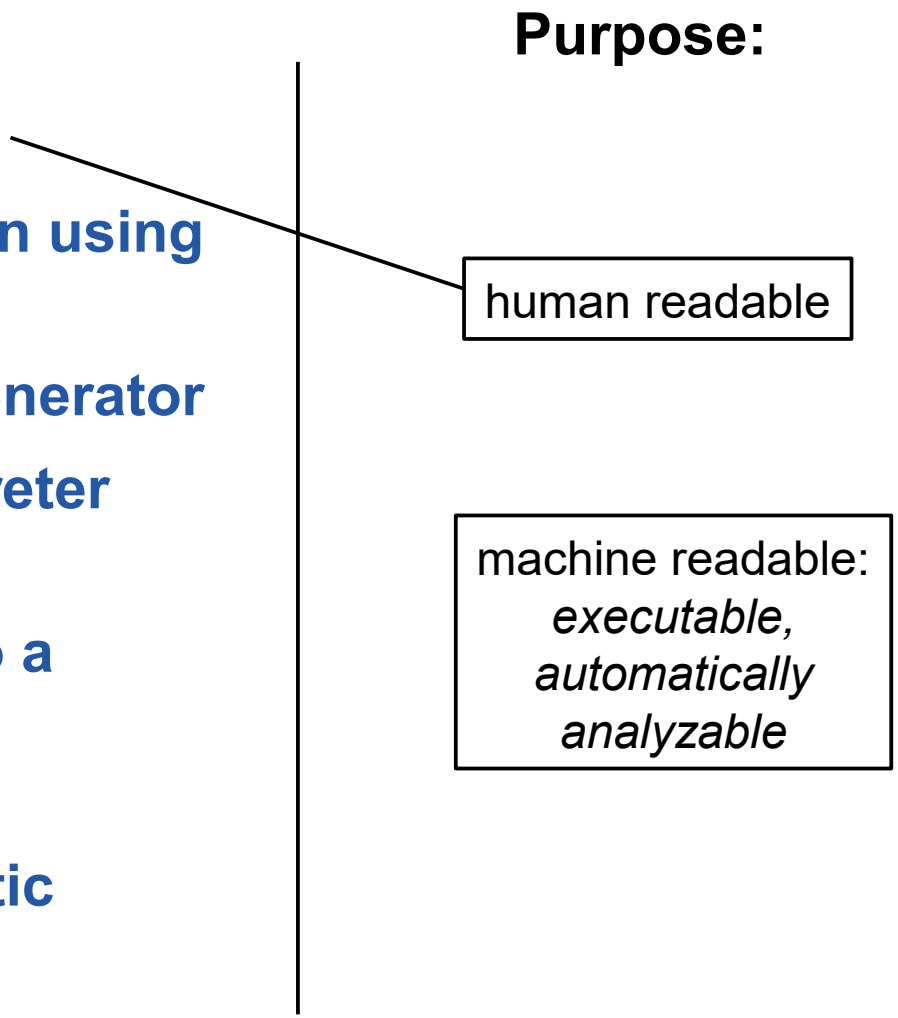

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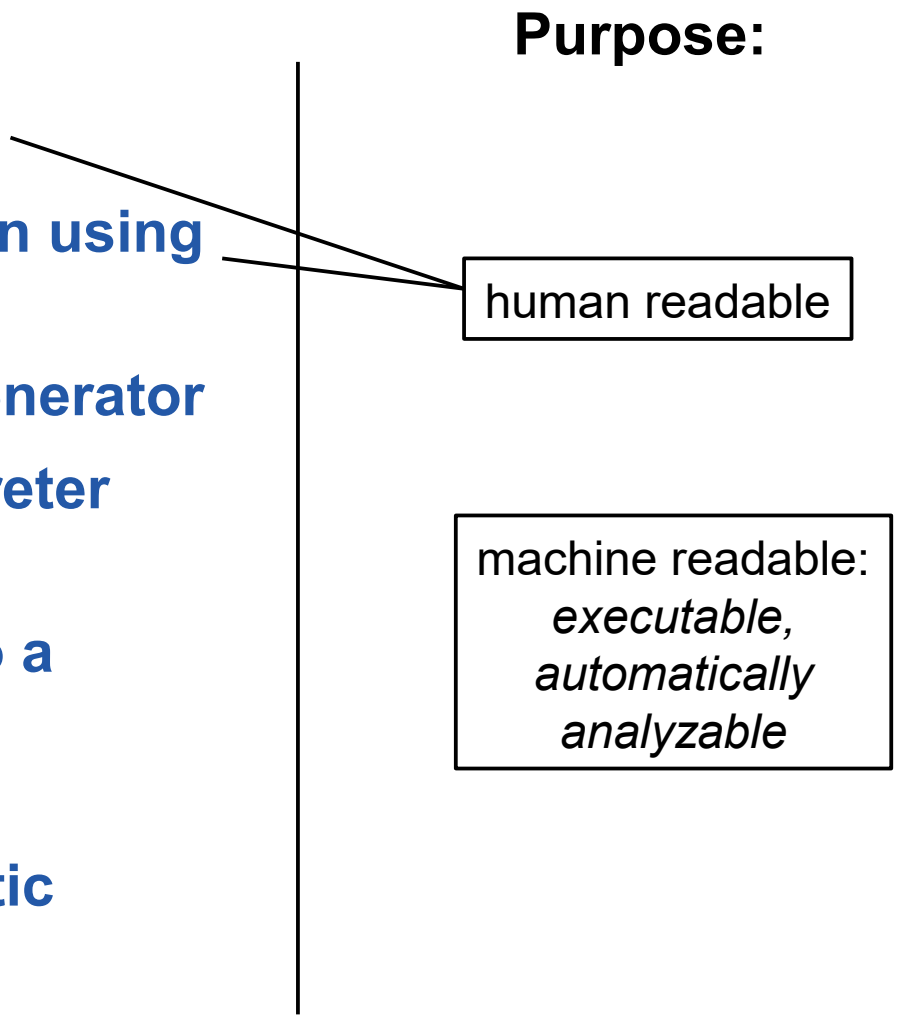

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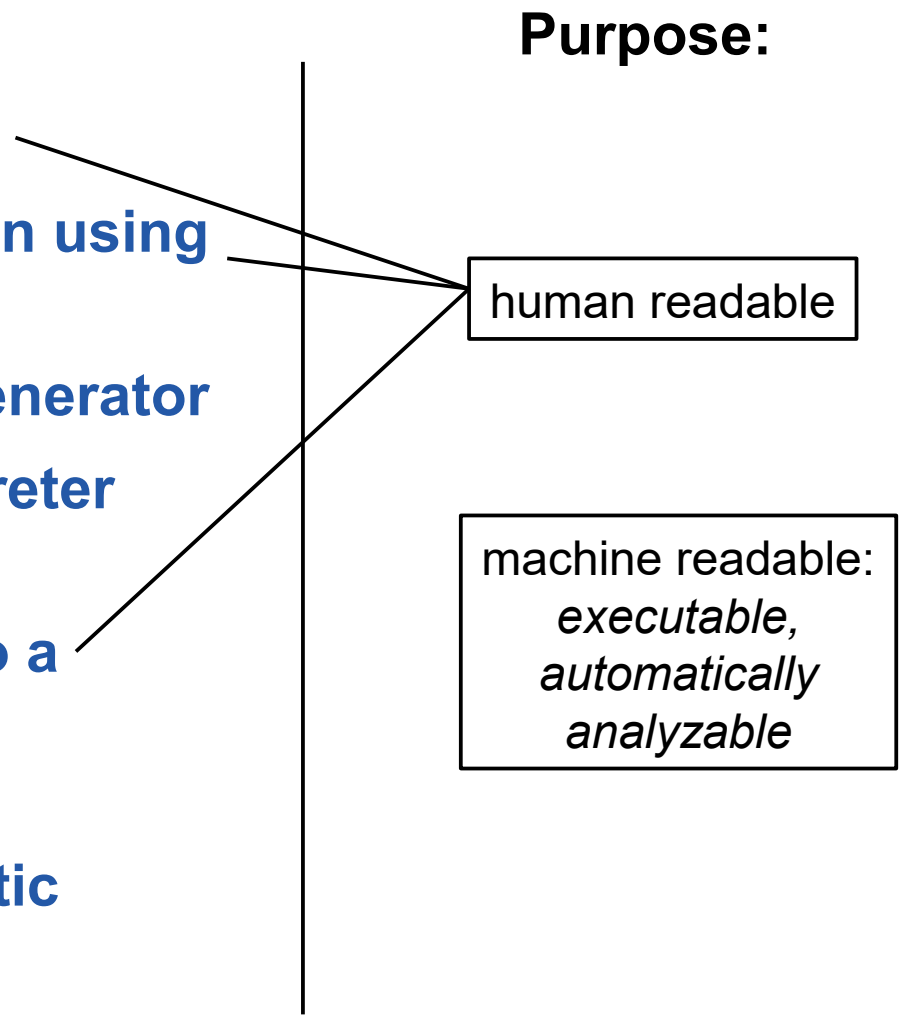

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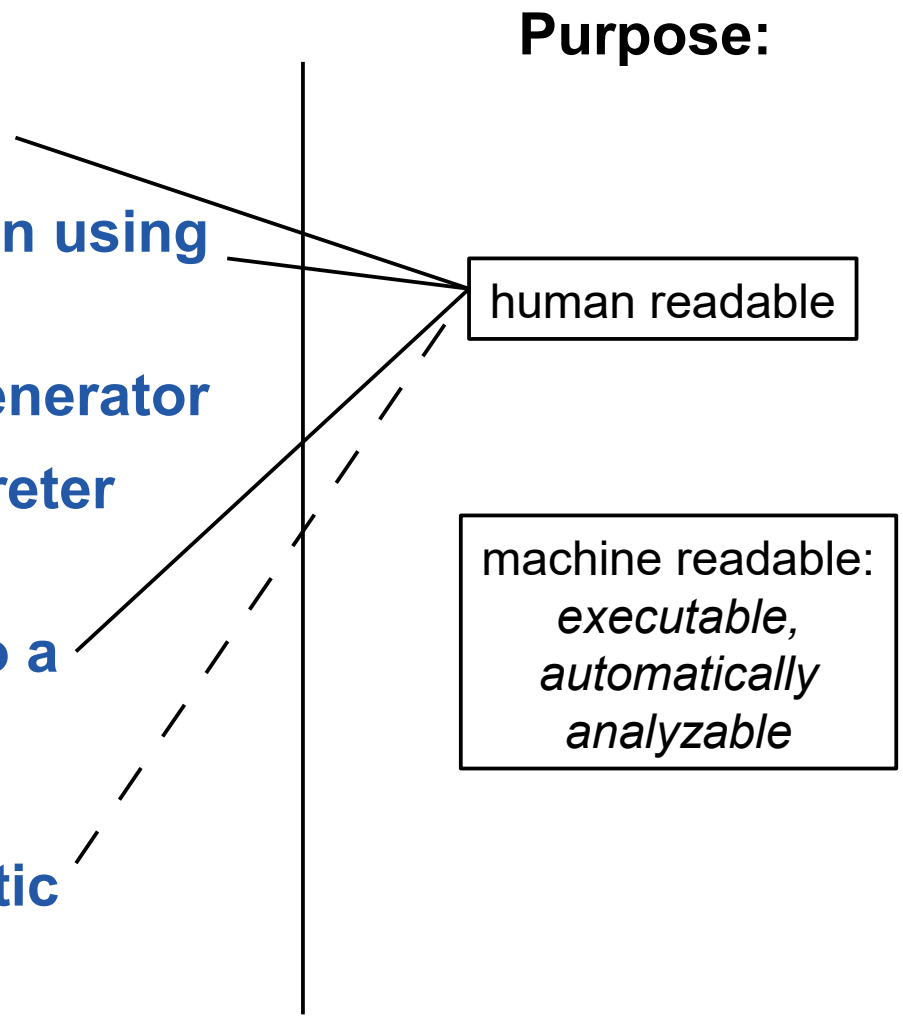

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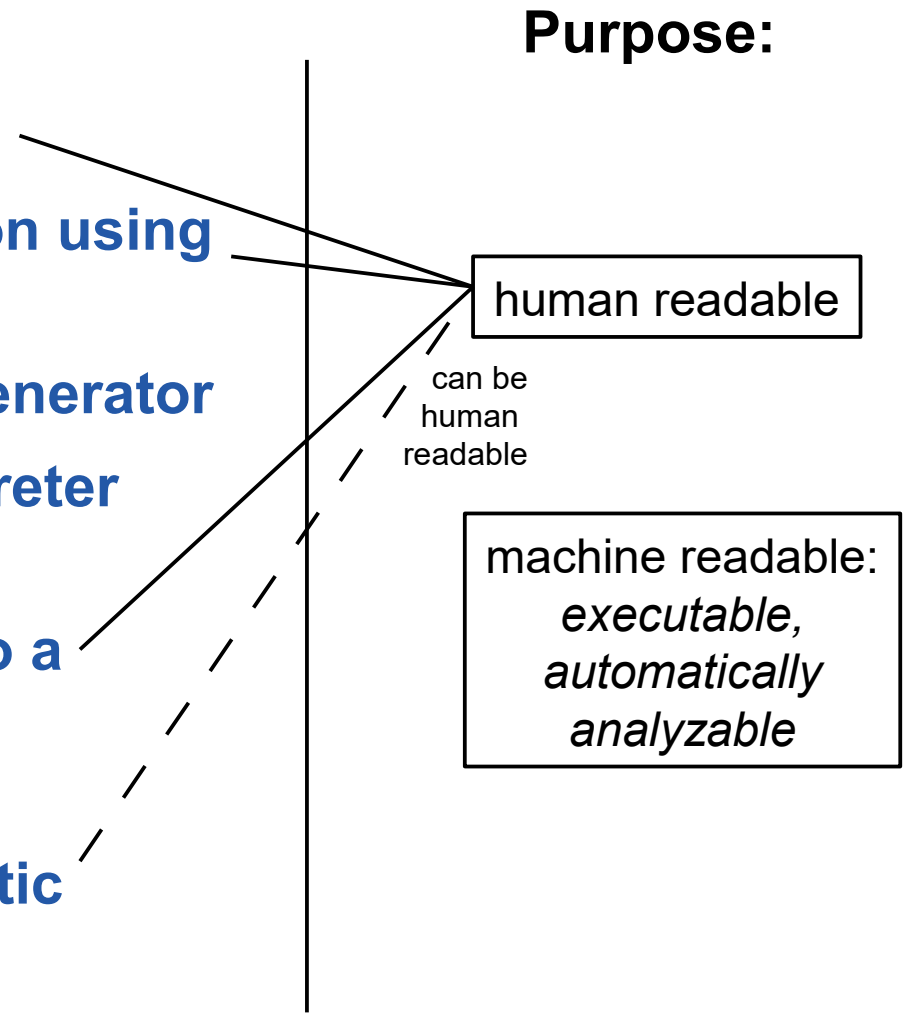

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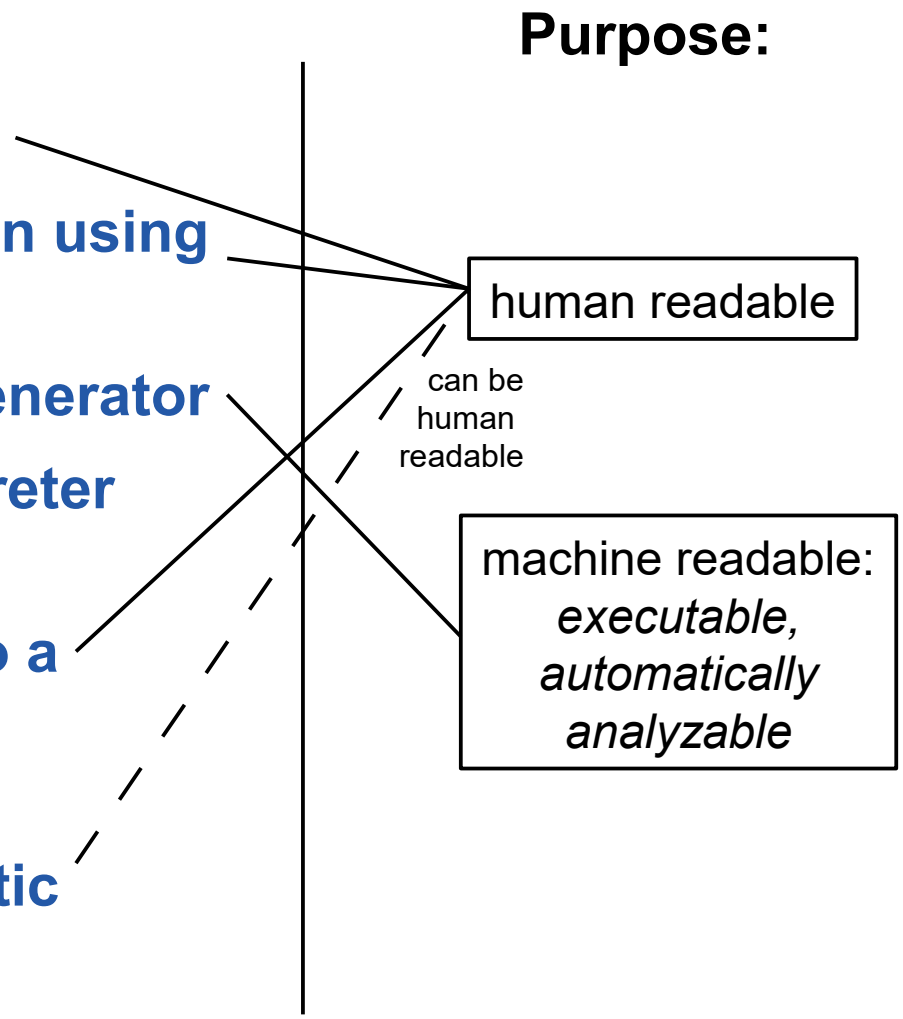

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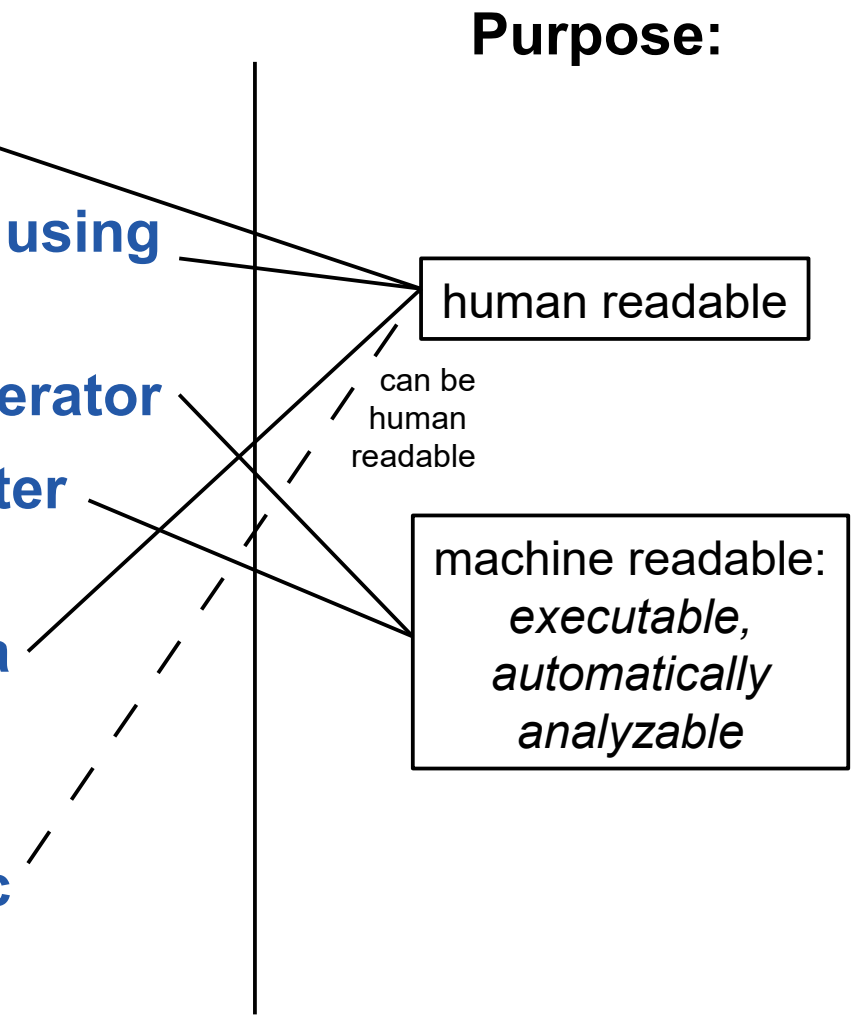

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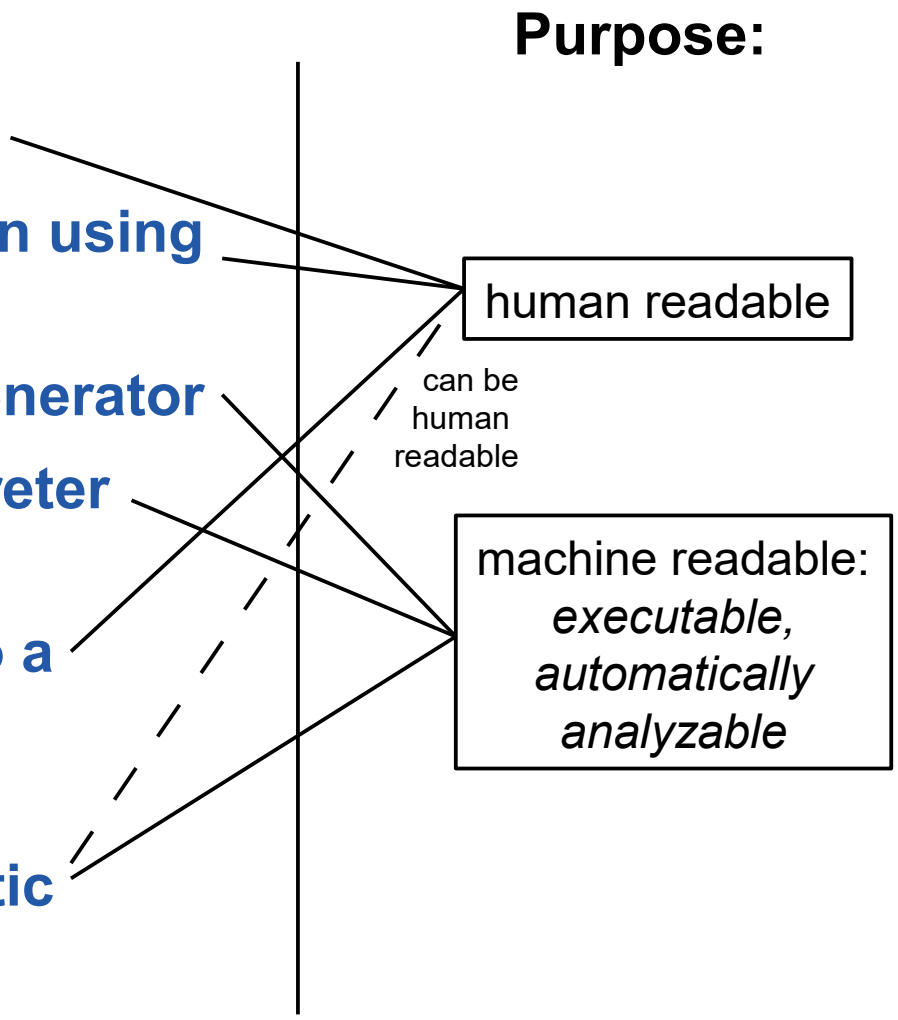

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- (Details of this method of semantics definitions will not be part of this lecture)

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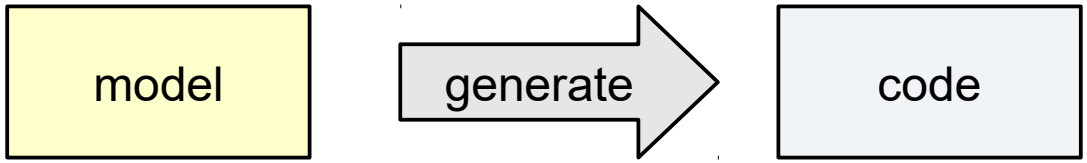

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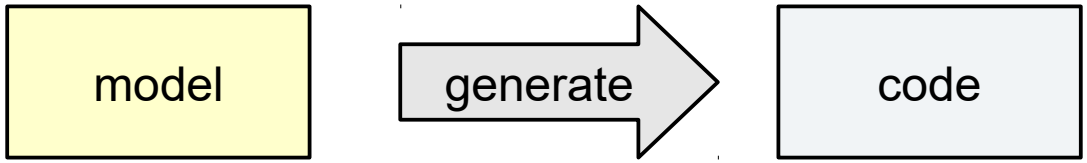

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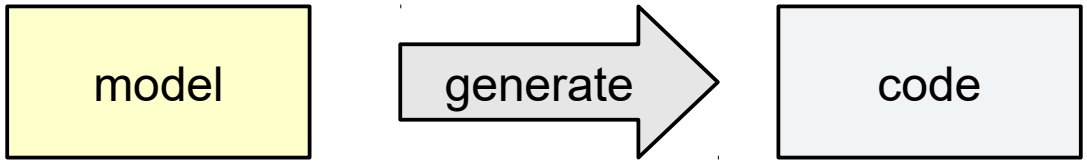

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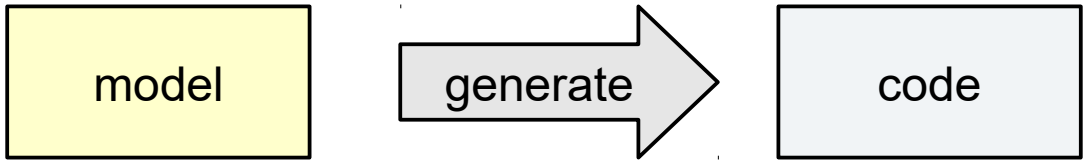

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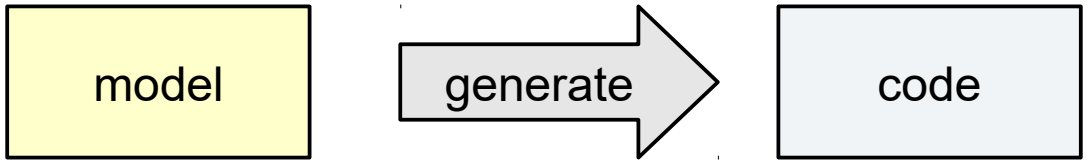

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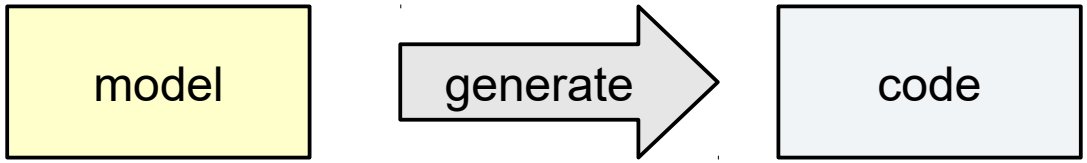

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    - or for which the semantics is defined **in the form of different virtual machine implementations**

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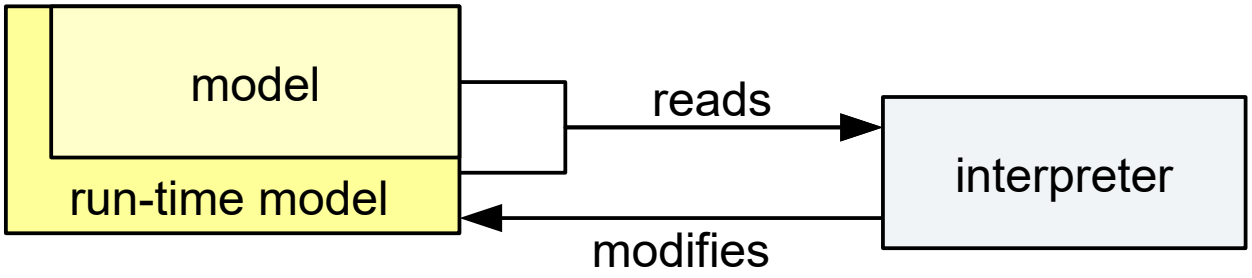

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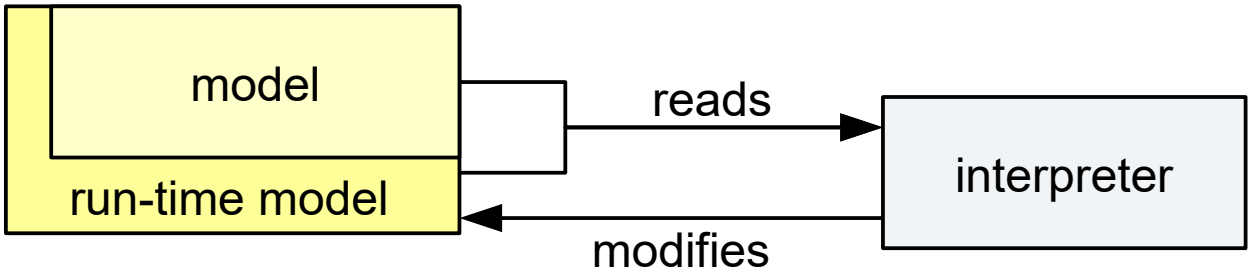

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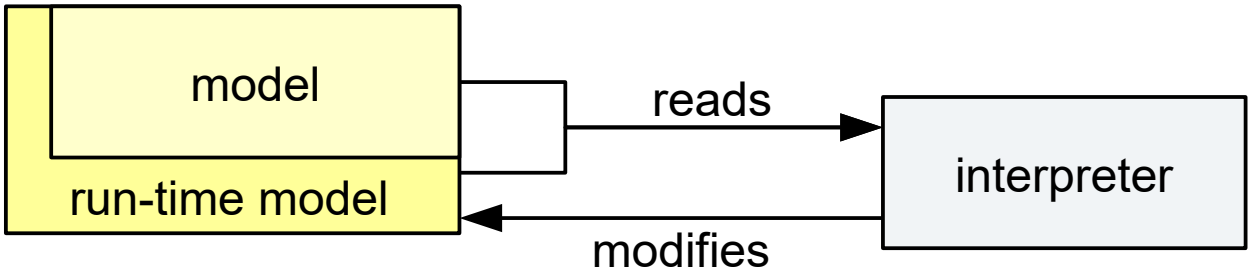
- The runtime extension part captures the "current state" of execution, which the interpreter can modify



Interpreter and Run-time Model Extension

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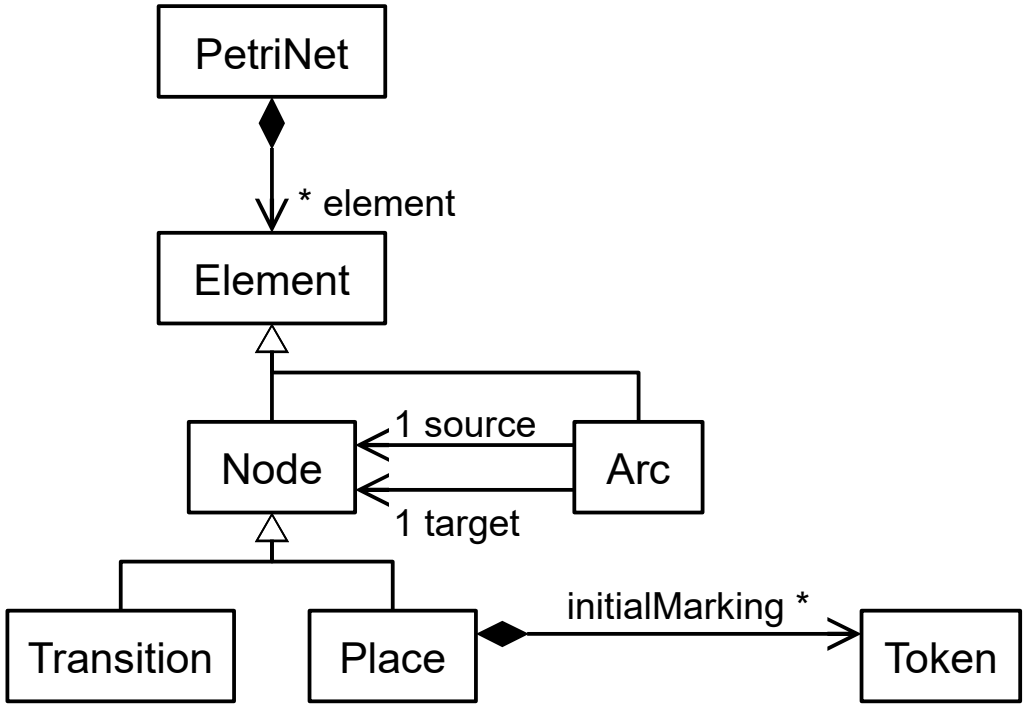

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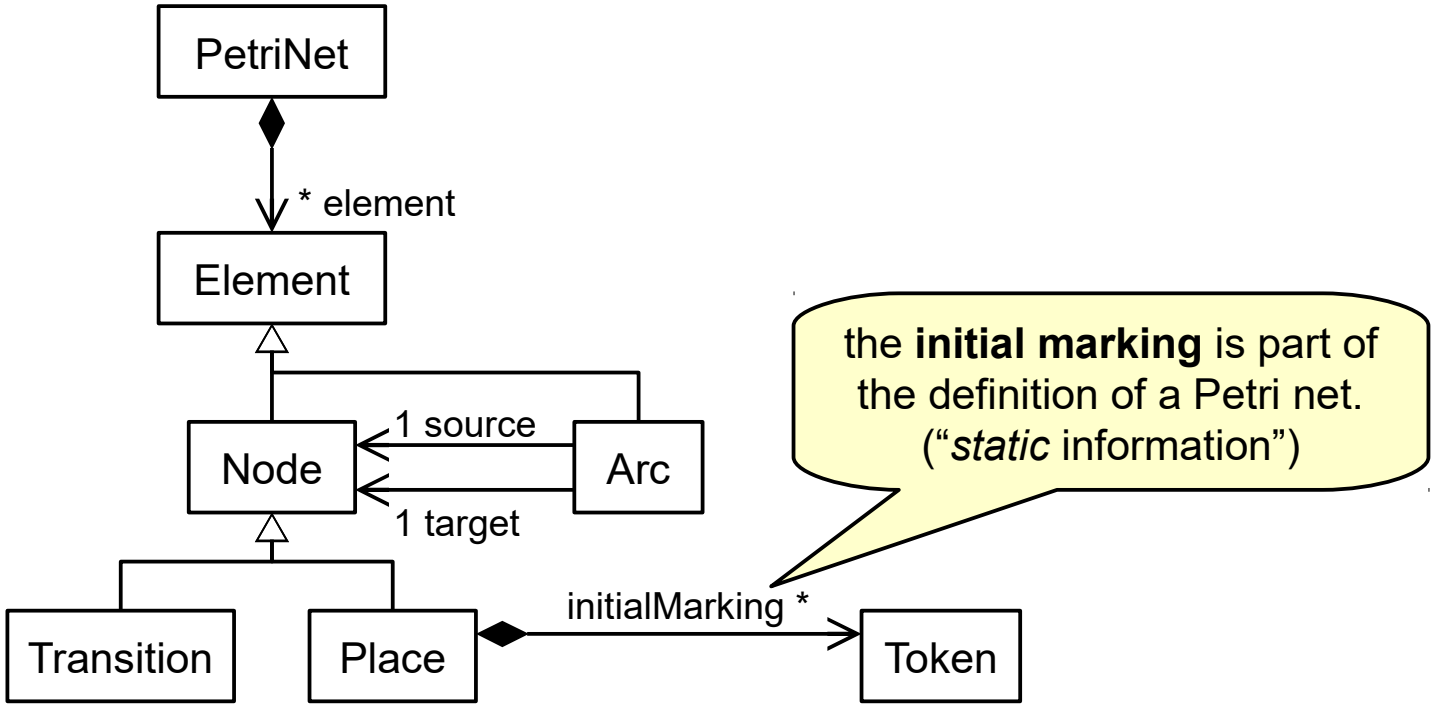

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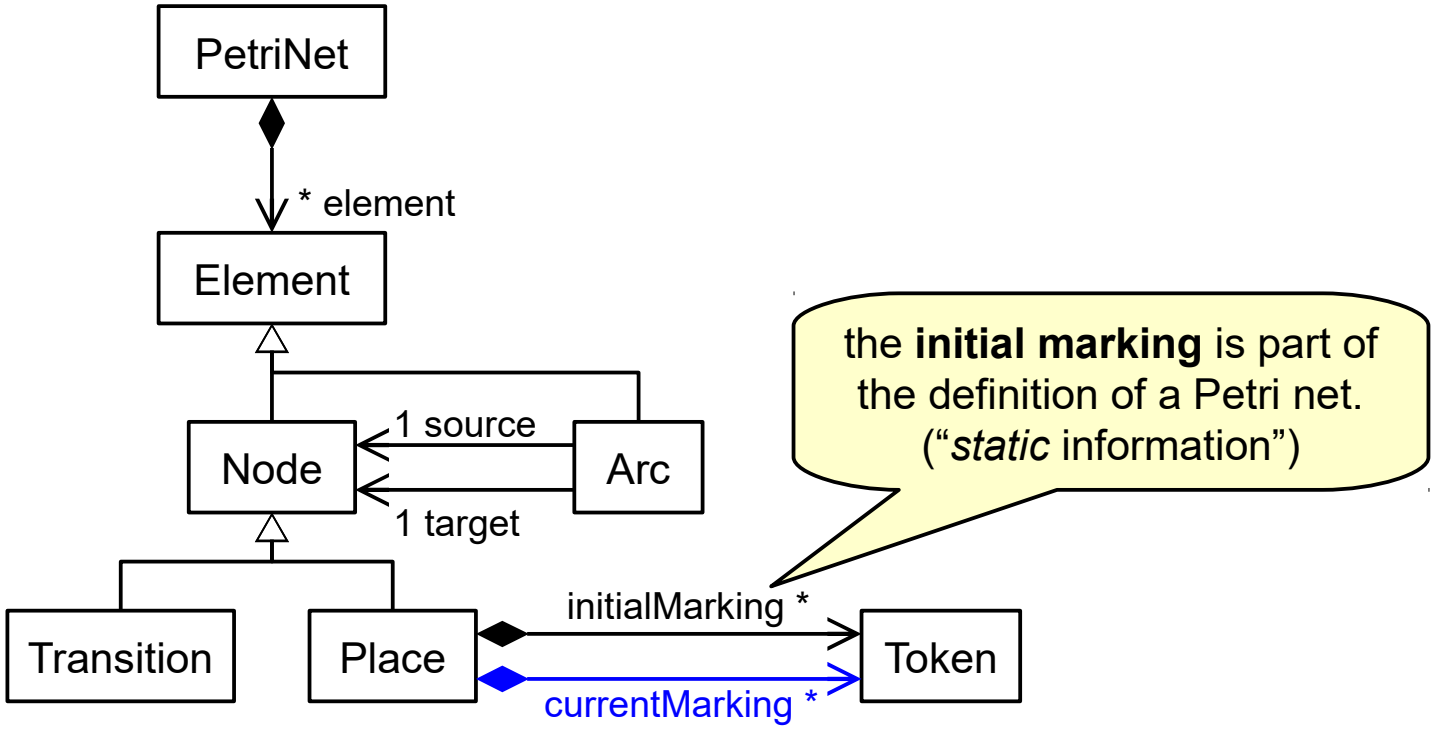

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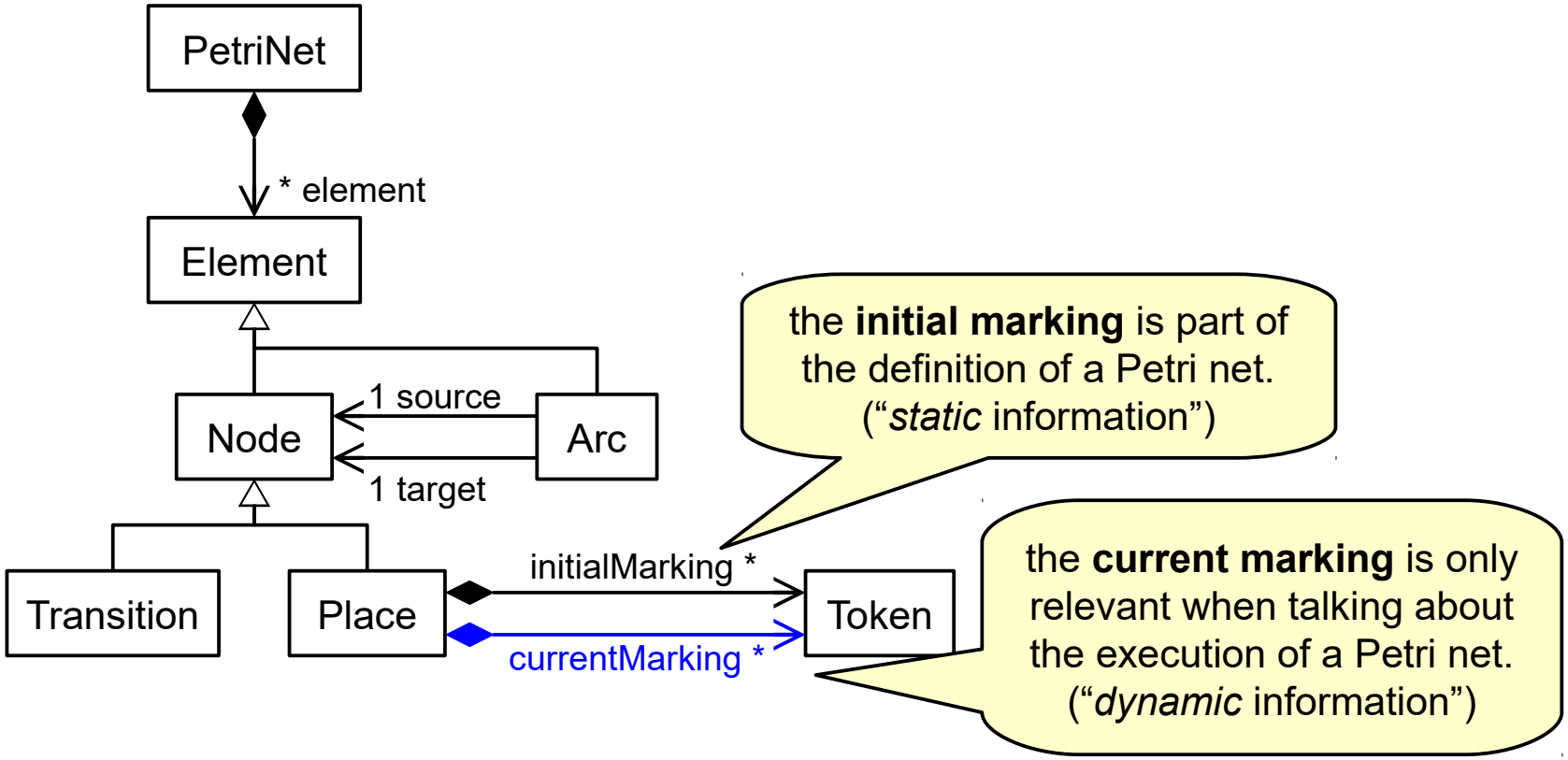

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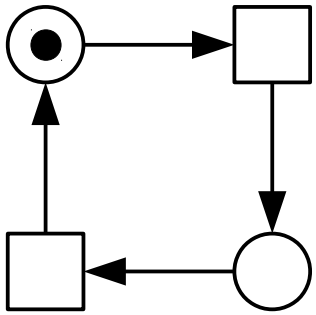

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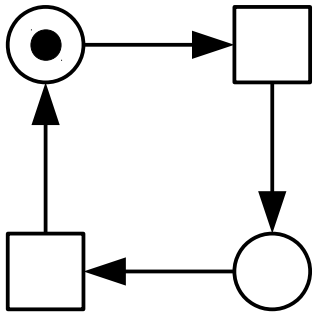

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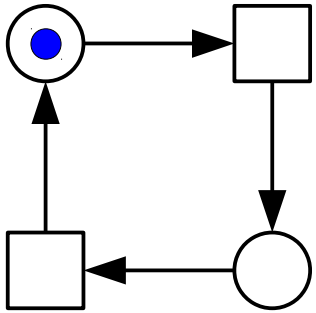

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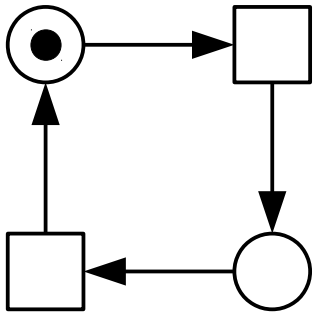

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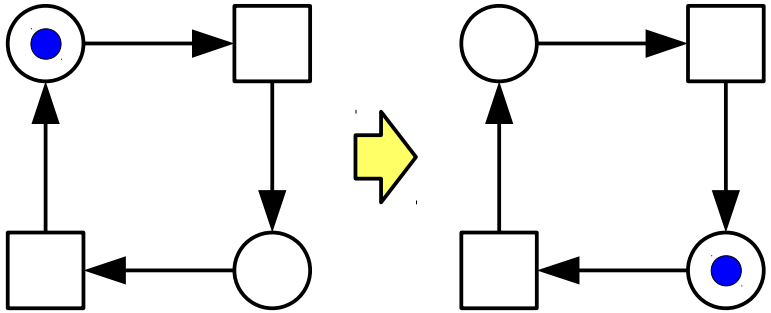

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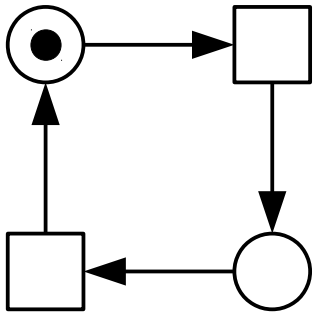

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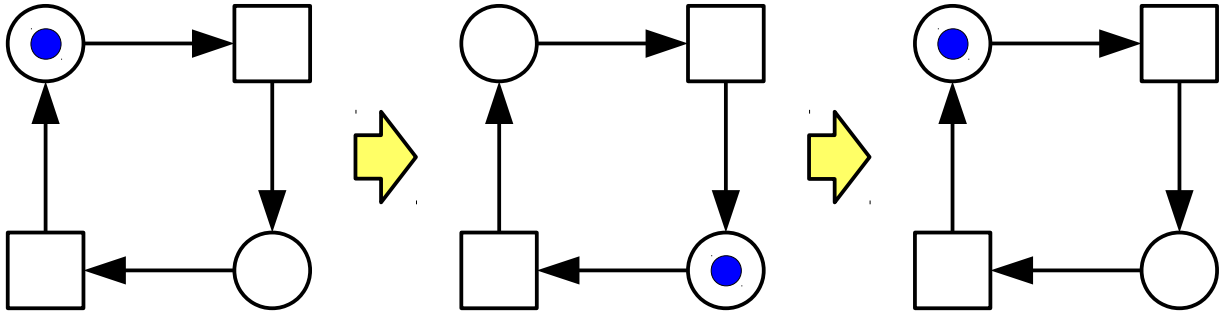

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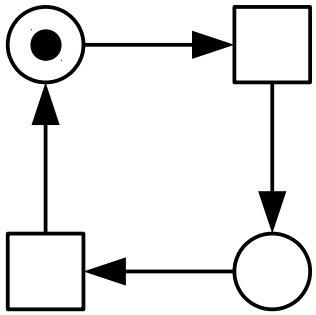

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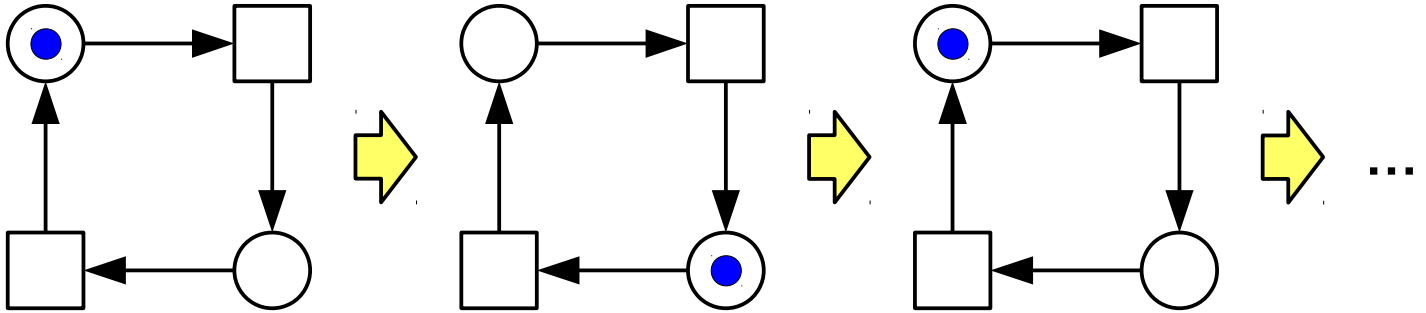

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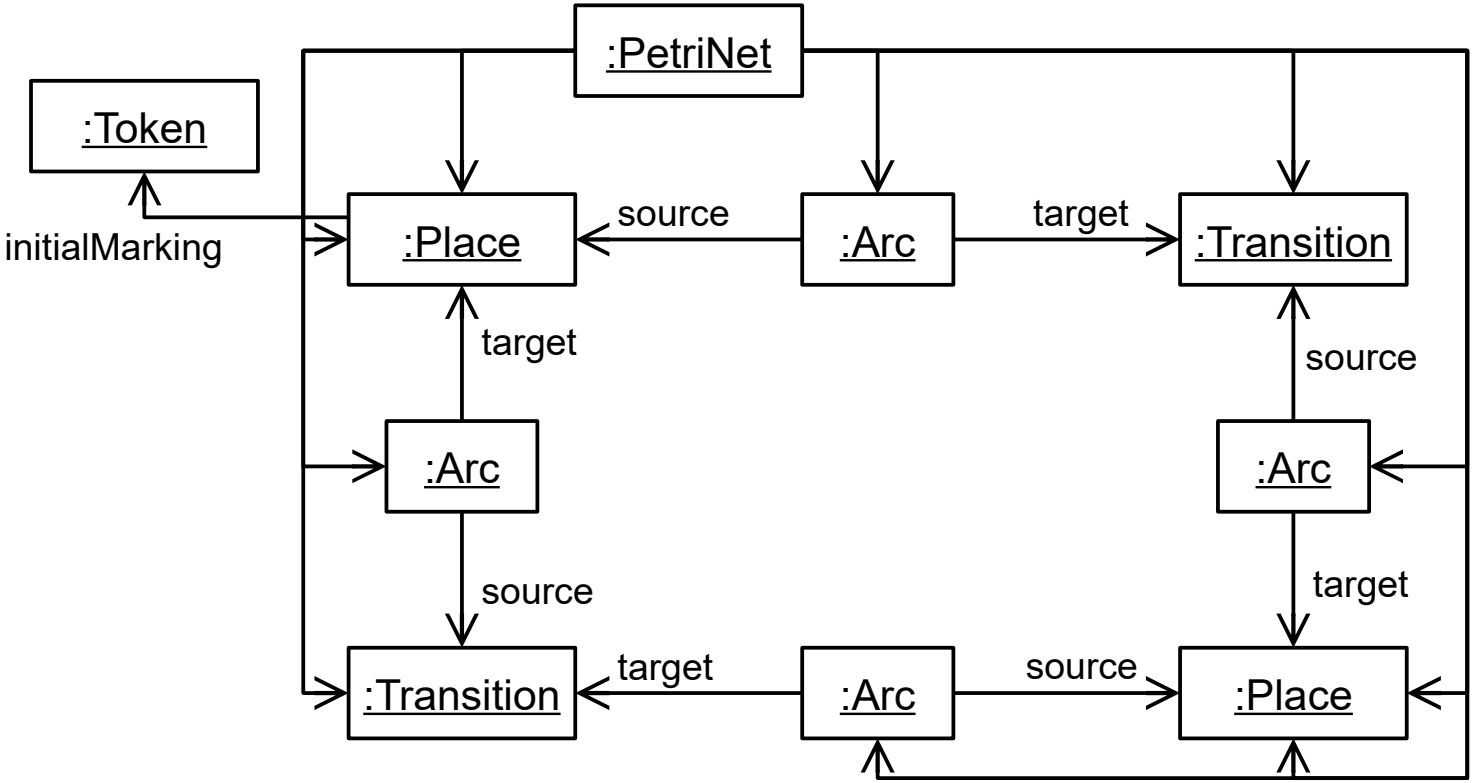

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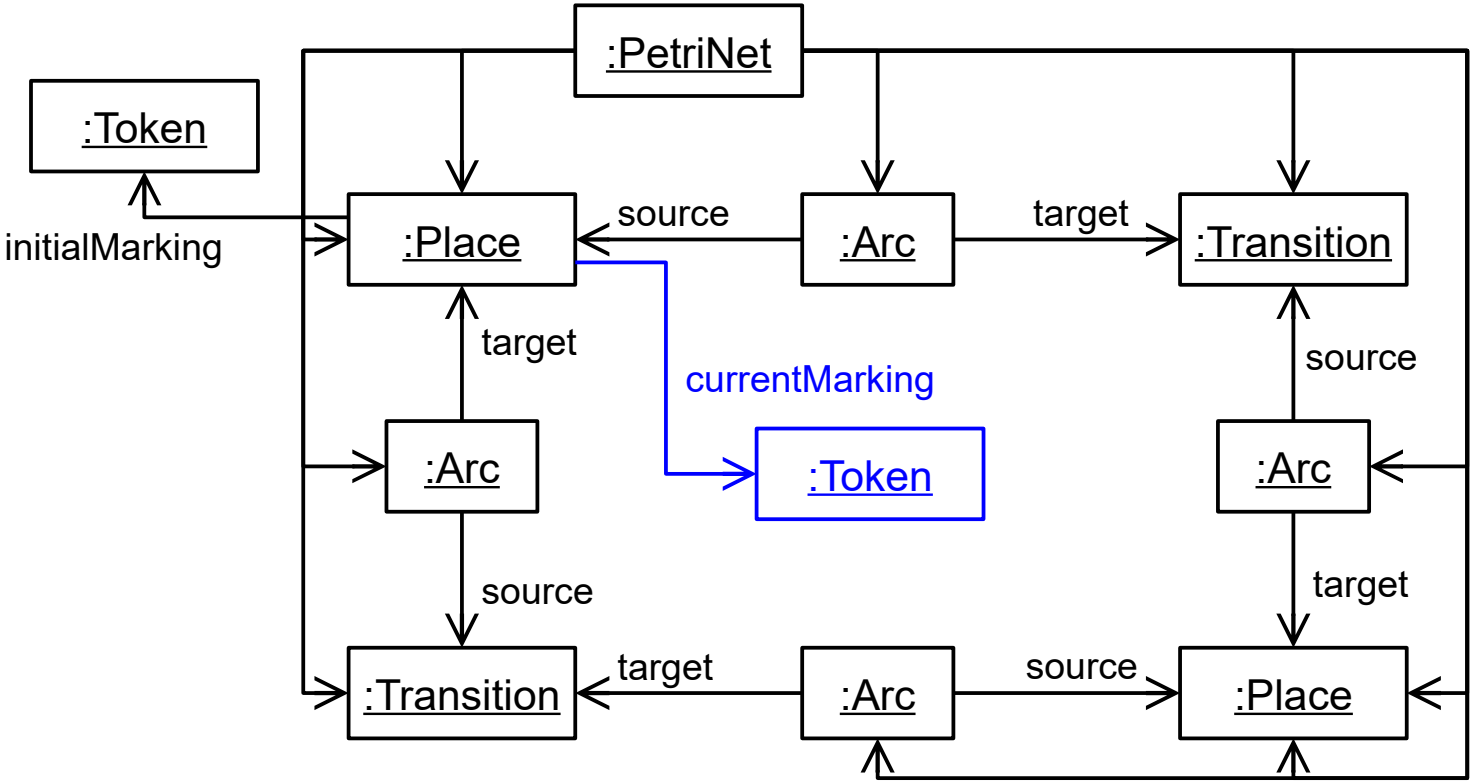

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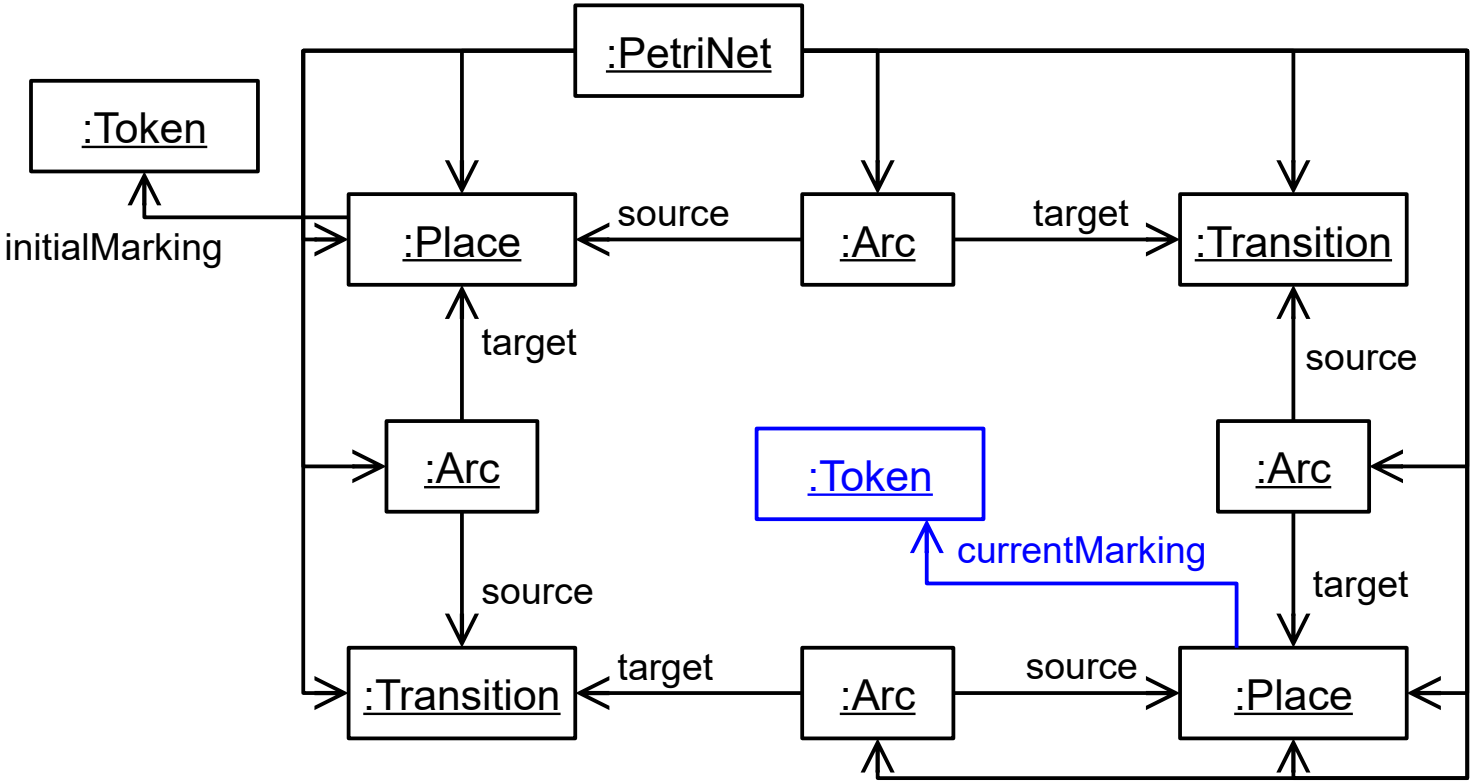

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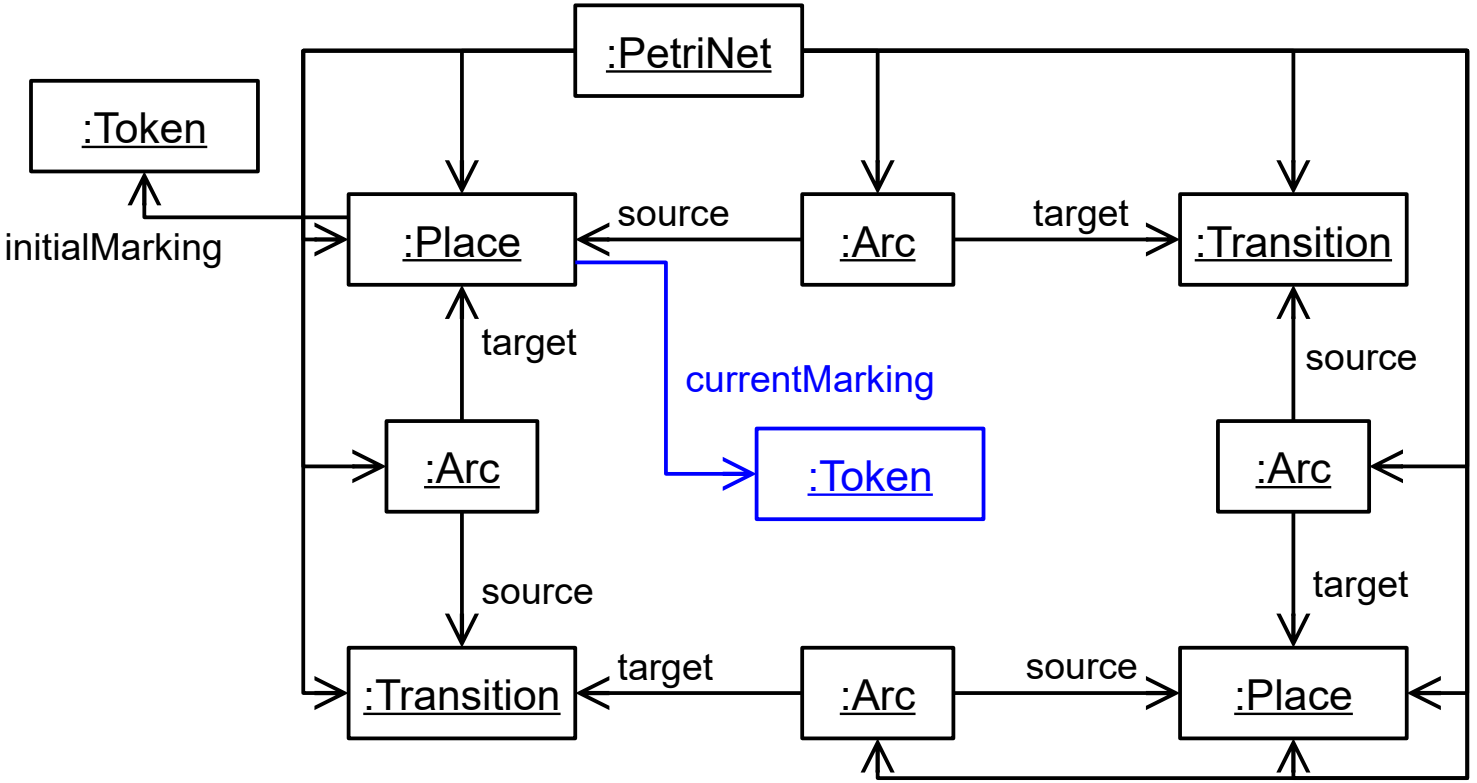

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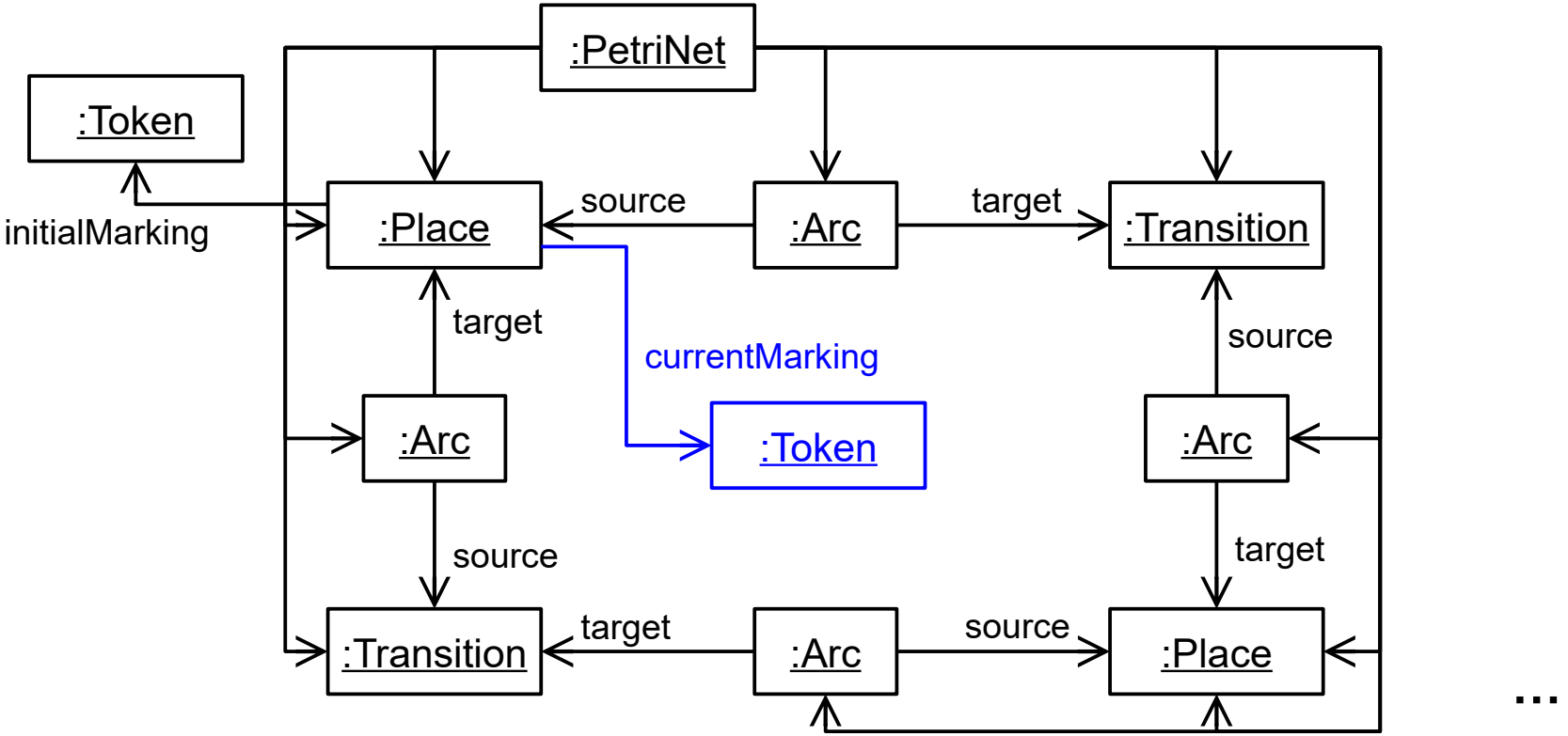

Interpreter and Run-time Model Extension

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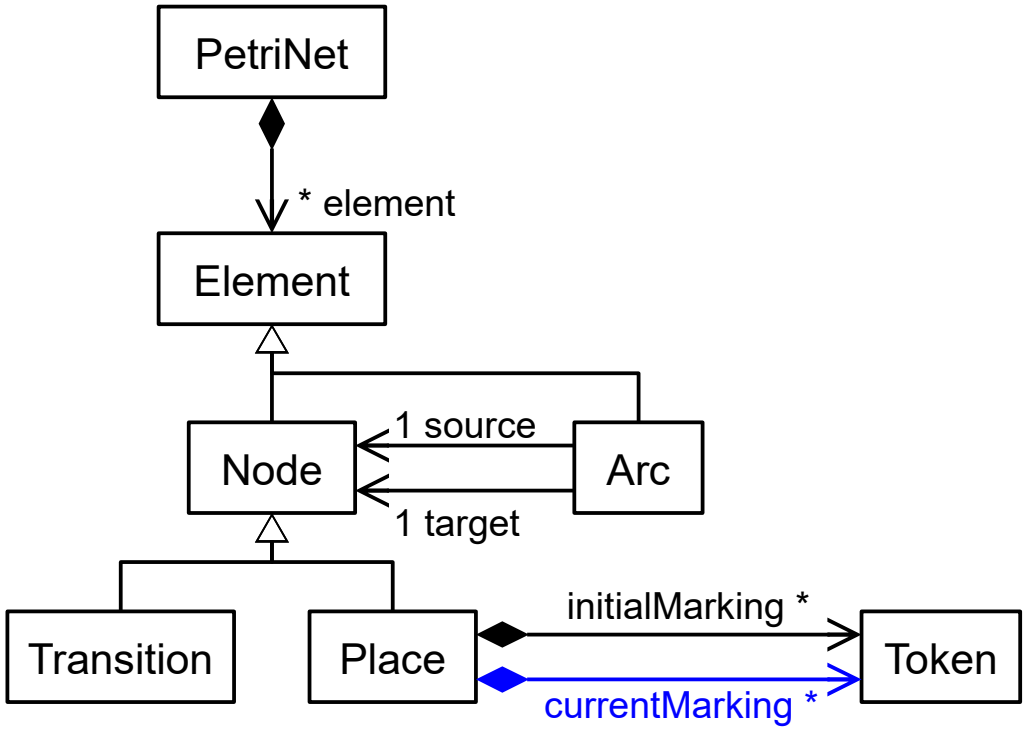

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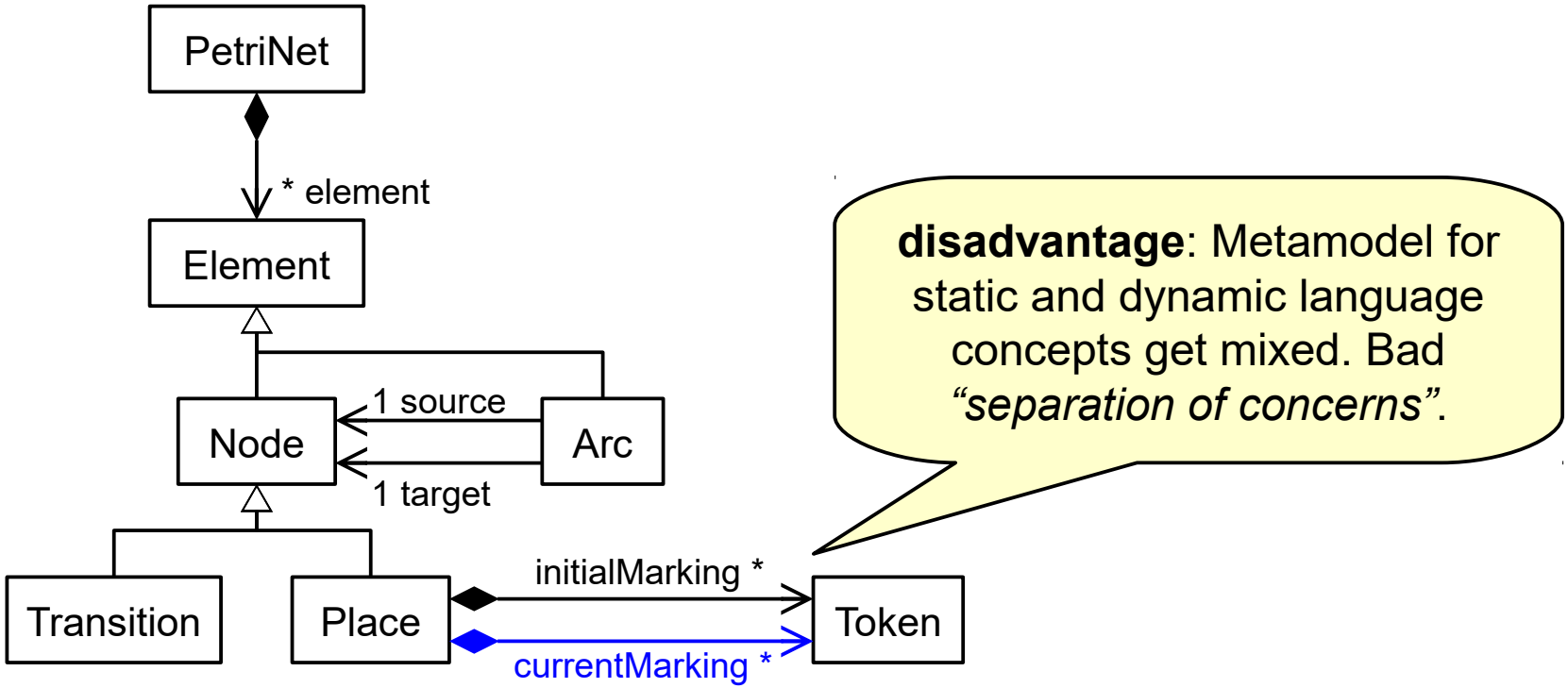

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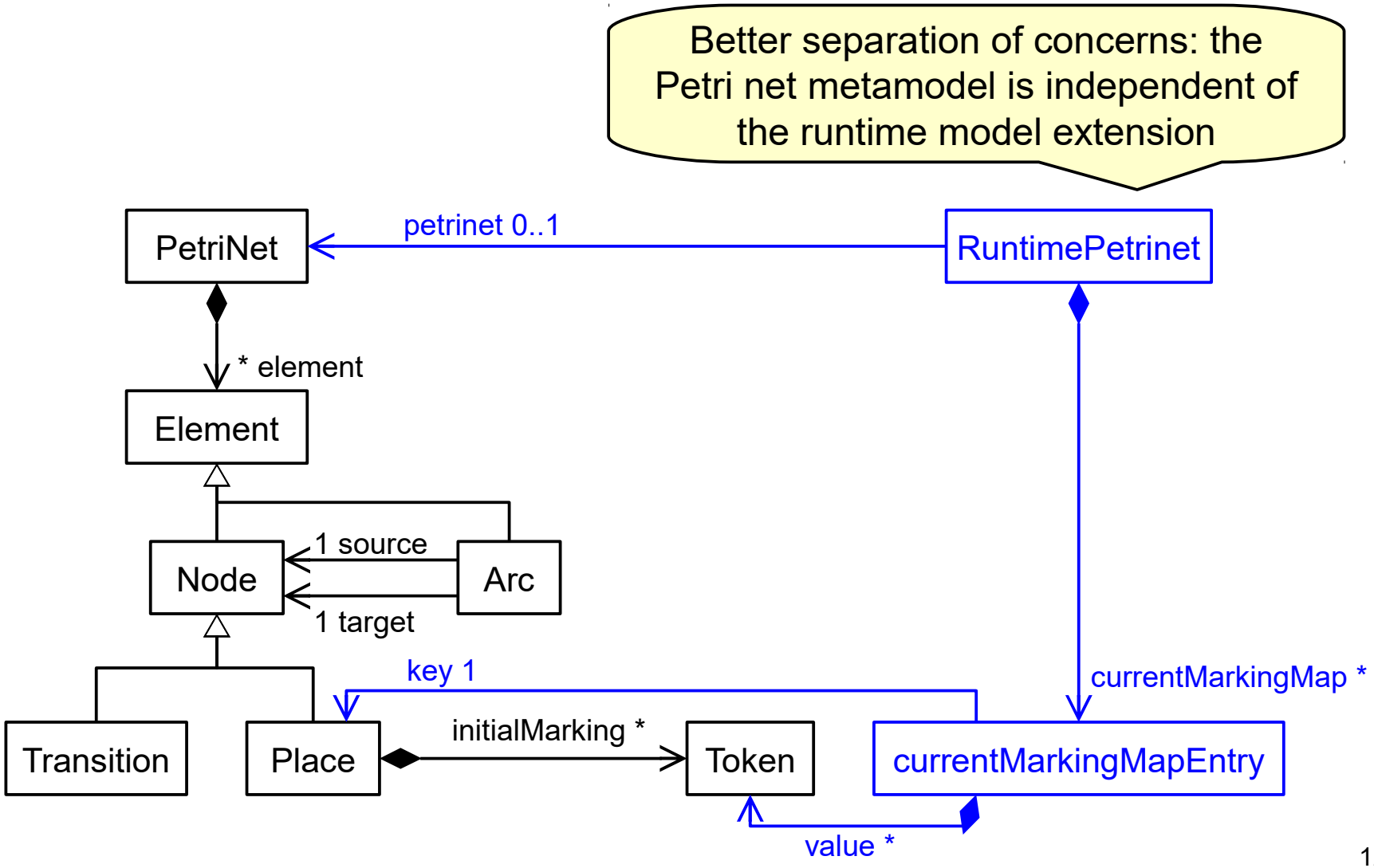
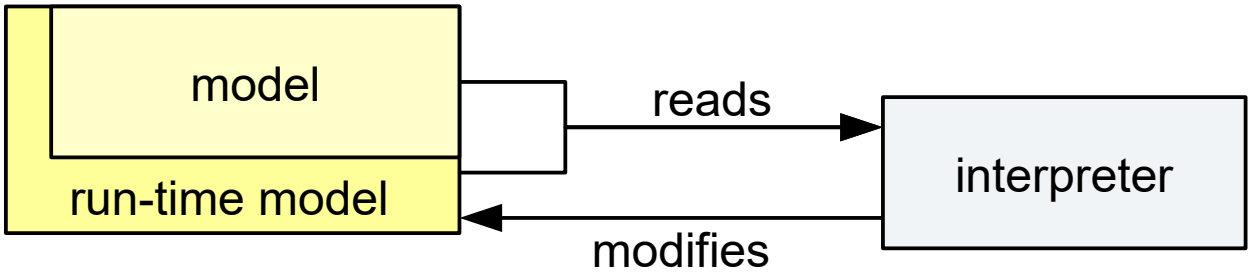
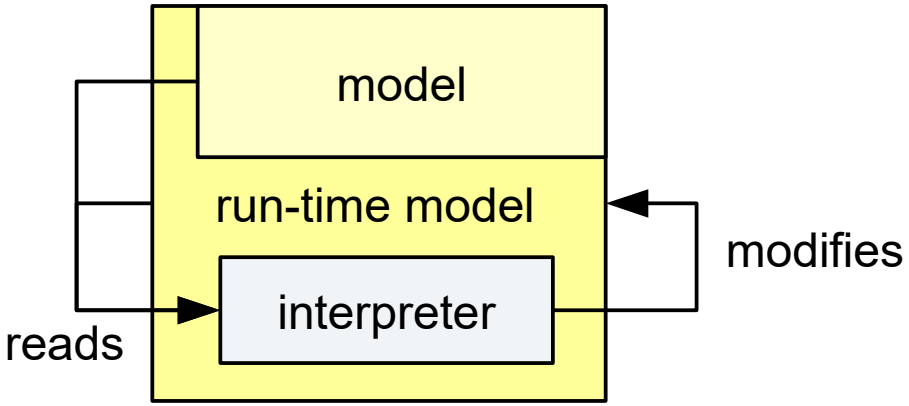


Interpreter and Run-time Model Extension

- The interpreter
  - can be an **external program** working on a Petri net model + runtime extension

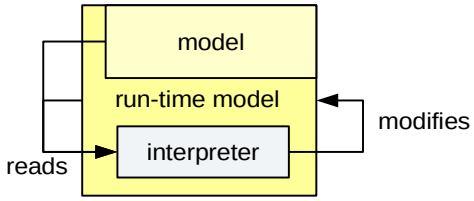


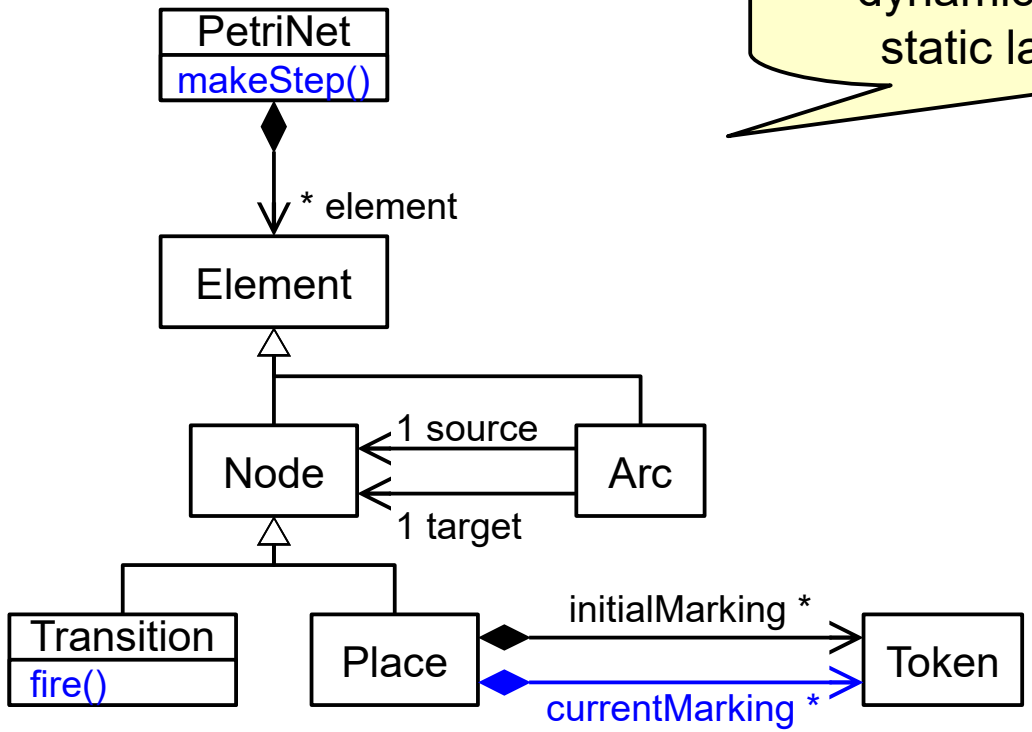
  - Or the interpreter can be part of the runtime model



Interpreter and Run-time Model Extension

- Example: Petri net interpreter part of the runtime model





again, bad separation of concerns: dynamic logic becomes part of static language metamodel.

Interpreter and Run-time Model Extension

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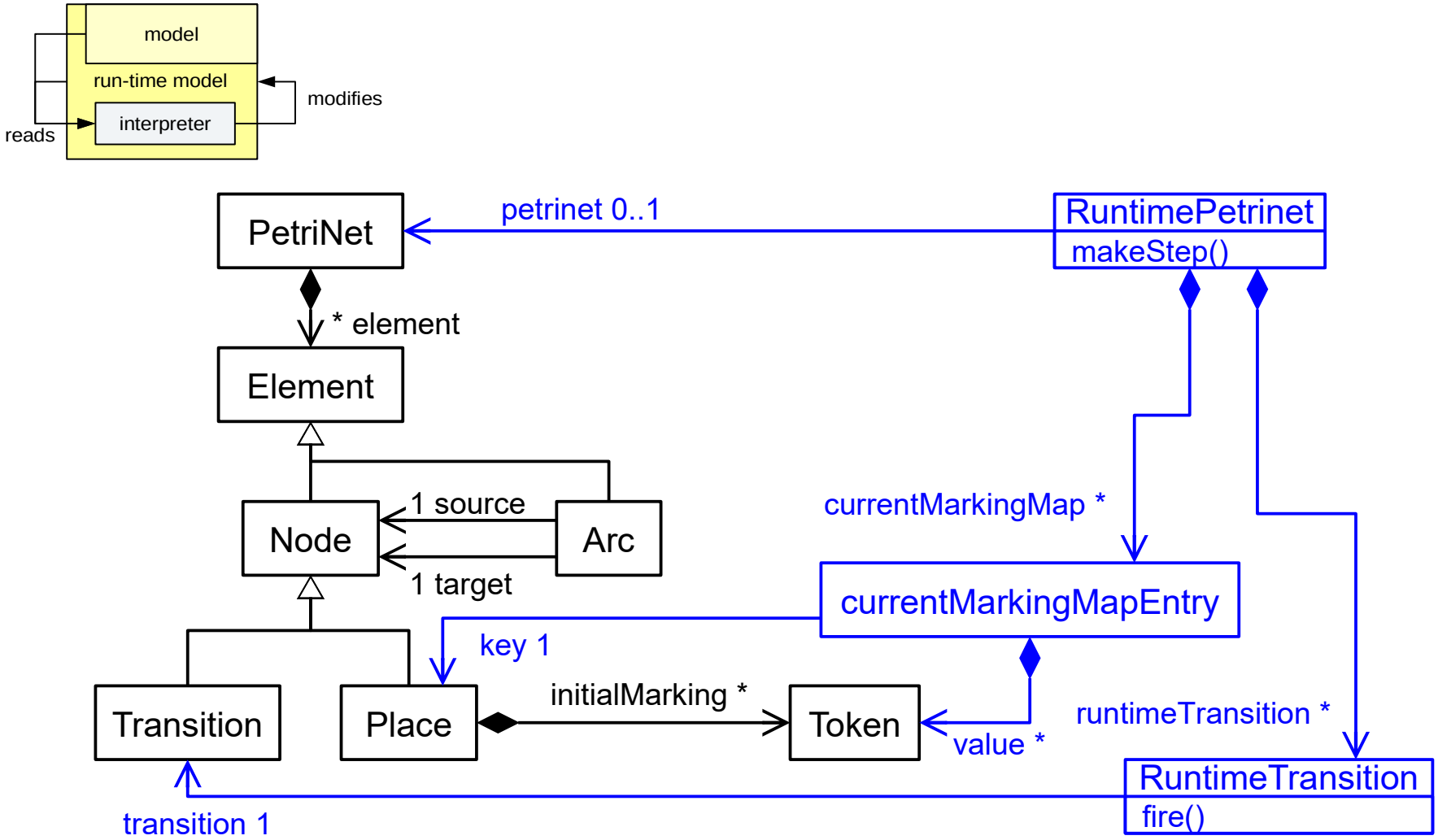

Interpreter and Run-time Model Extension

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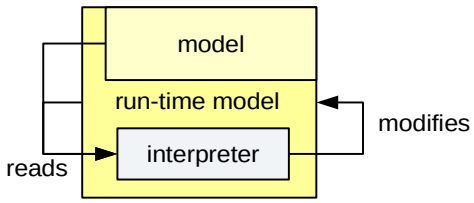
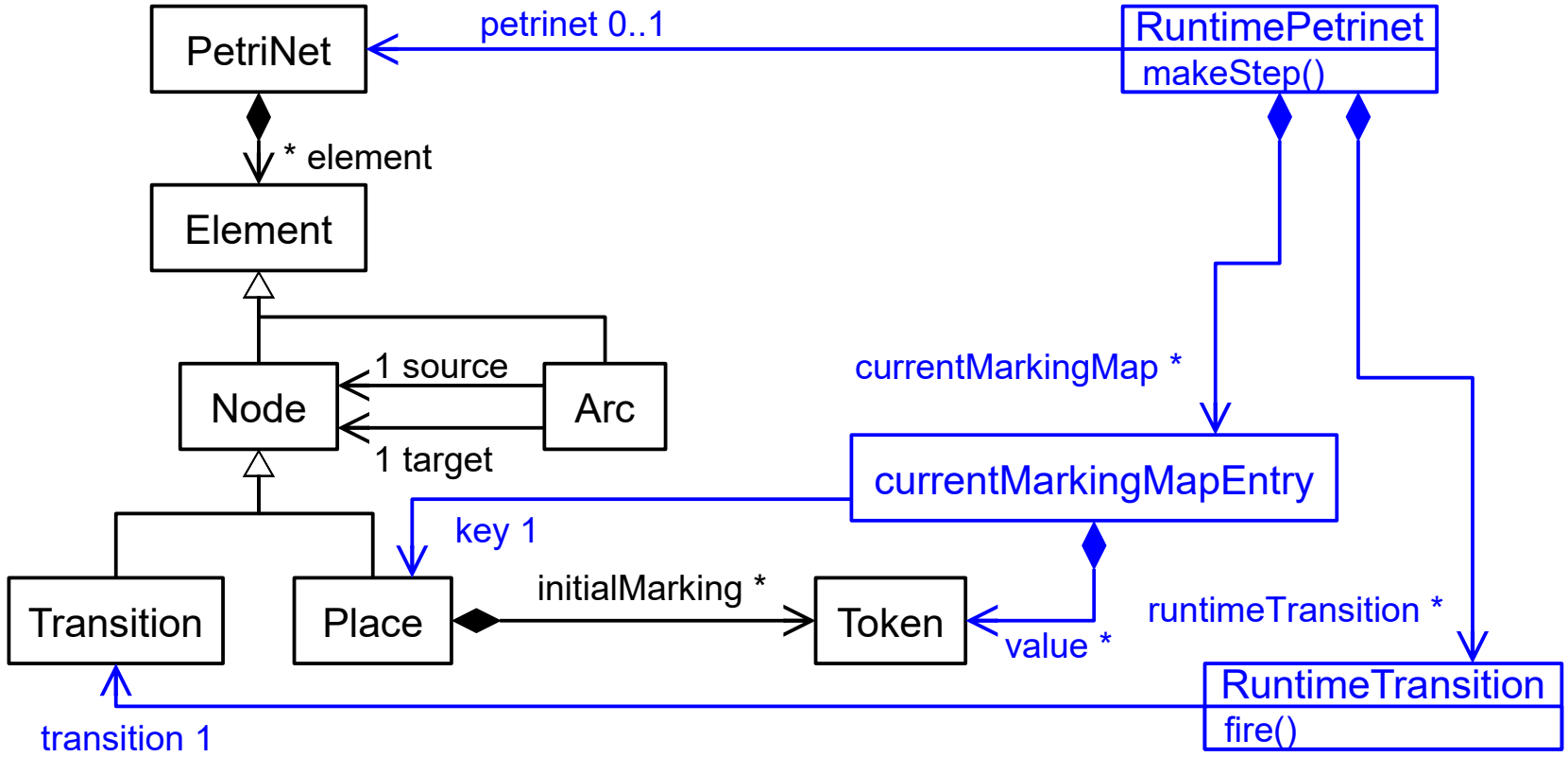


Better separation of concerns: the dynamic logic becomes part of the runtime model extension



Interpreter and Run-time Model Extension

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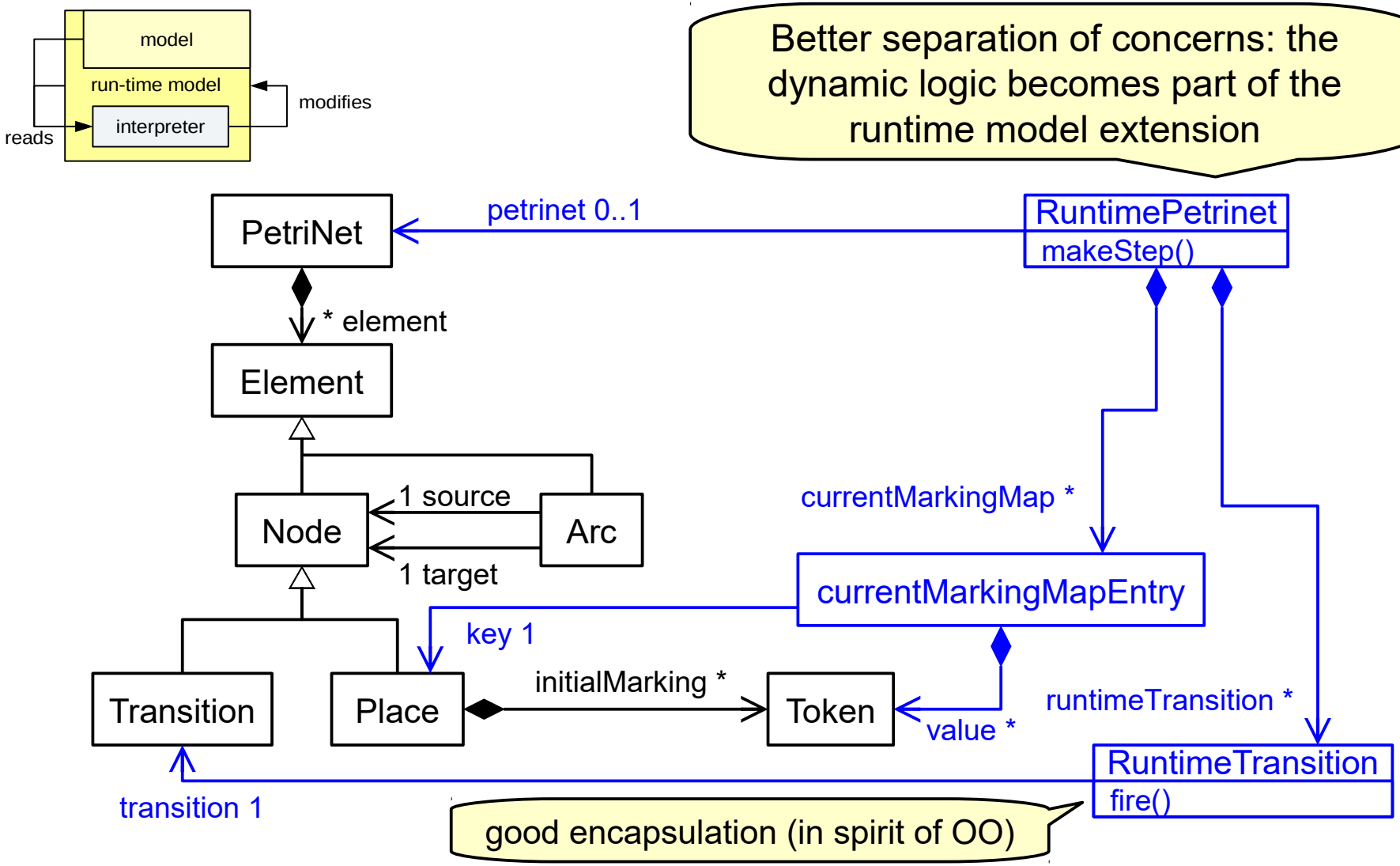
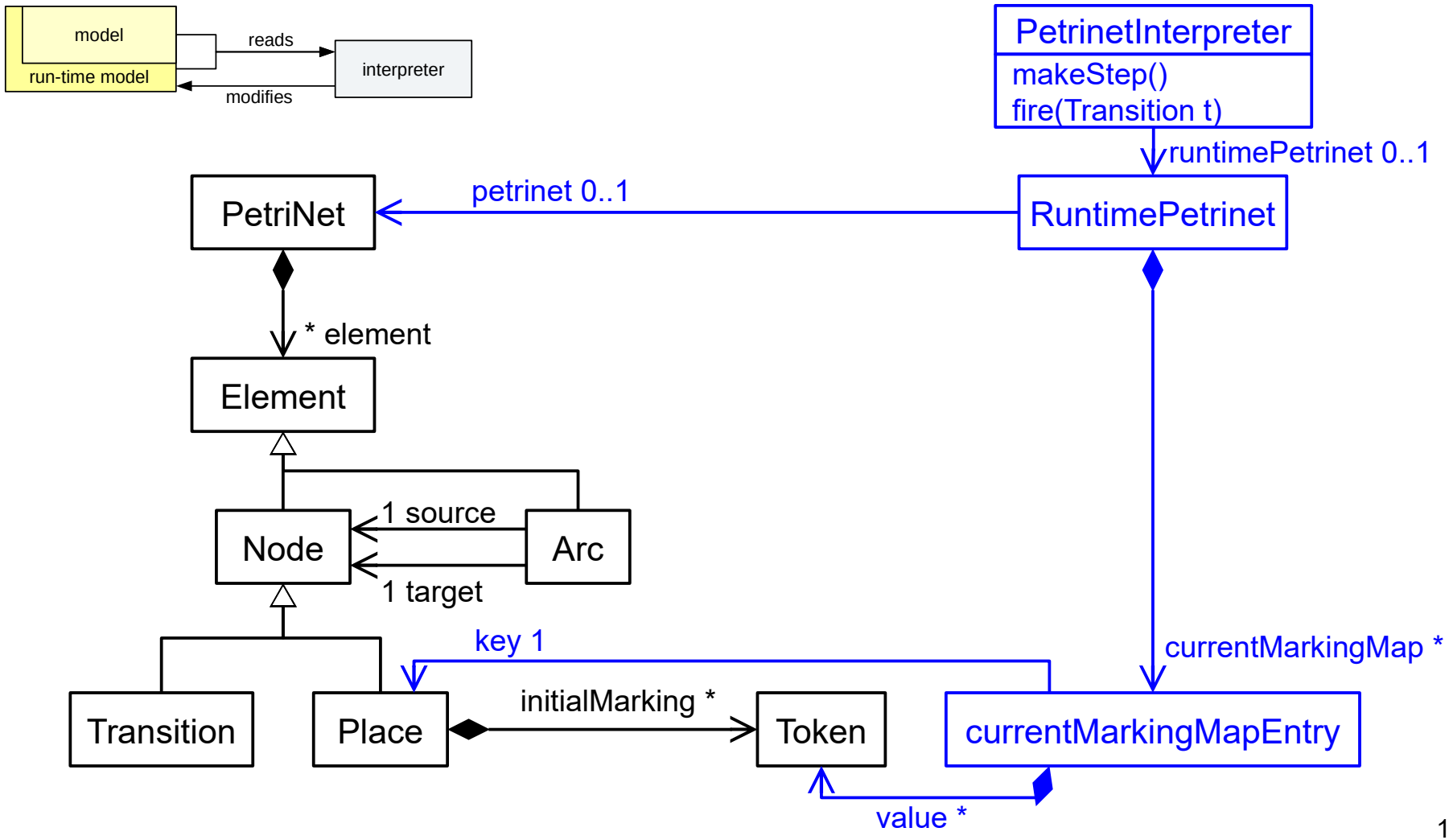


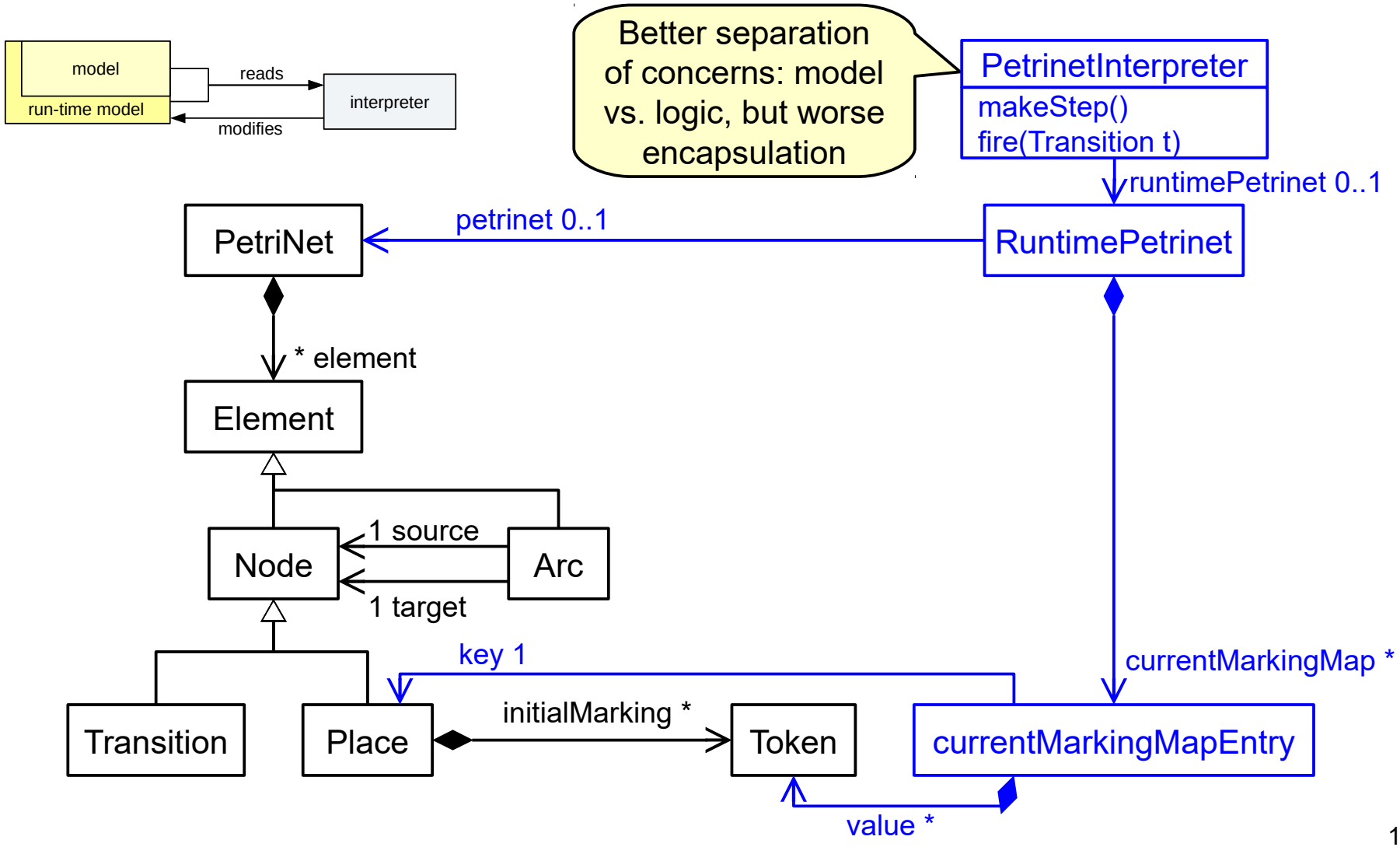
Interpreter and Run-time Model Extension

- Example: Petri net interpreter externally



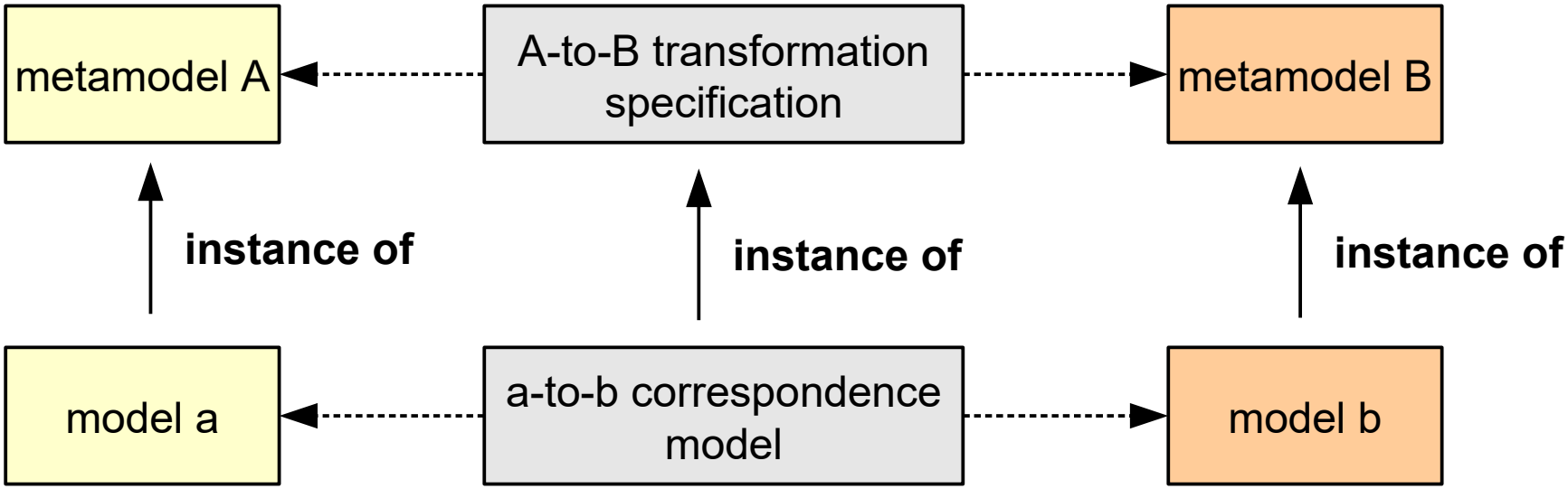
Interpreter and Run-time Model Extension

- Example: Petri net interpreter externally



Model-to-Model Transformations

- A typical way to view model-to-model transformations
  - transformation from language A to language B
  - the transformation specification refers to metamodels A and B
  - sometimes: the transformation creates a *correspondence model* of how specifically elements of model a and b relate



Model-Driven Architecture (MDA)

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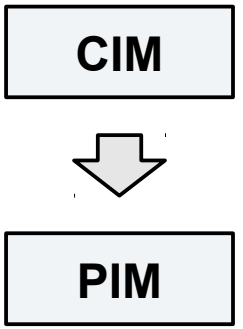

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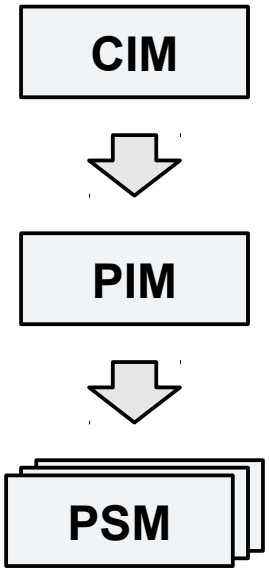

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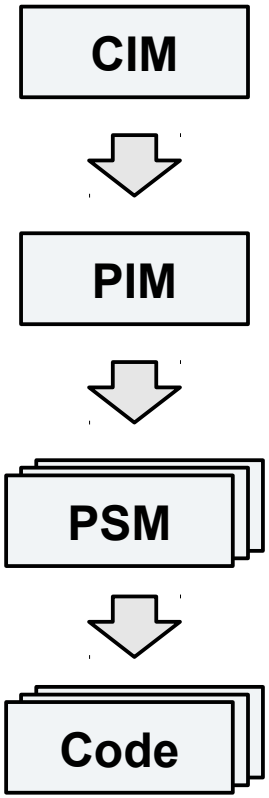


SOFTWARE ENGINEERING

5.2. Model-to-text transformation (code generation)

Leibniz Universität Hannover

Model-to-Text Transformations

- Model-2-Text transformations transform models into code or code-like artifacts
  - Java code
  - XML-Files
  - Configuration files
  - Documentation...

- This is a special case of model-2-model transformation that deserves special treatment and techniques.

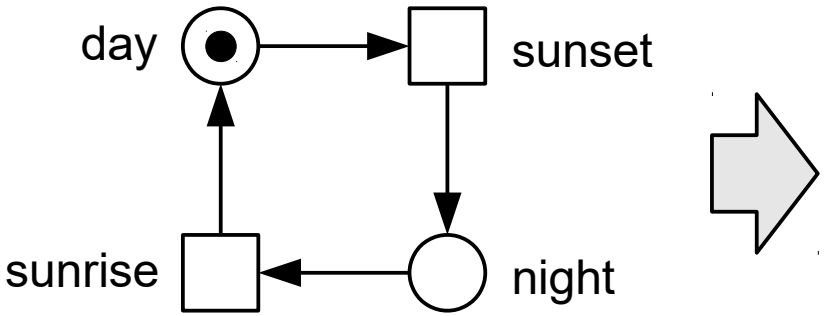
SOFTWARE ENGINEERING

Model-to-Text Transformations

- Different ways to realize Model-to-Text Transformations
  - Program transformation using Java / Xtend
  - use a template engine
    - Jet, Velocity, XPand, …

Example: Petrinet to Java

- Example:



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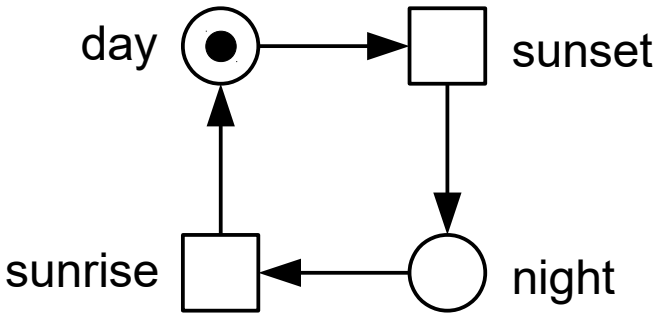
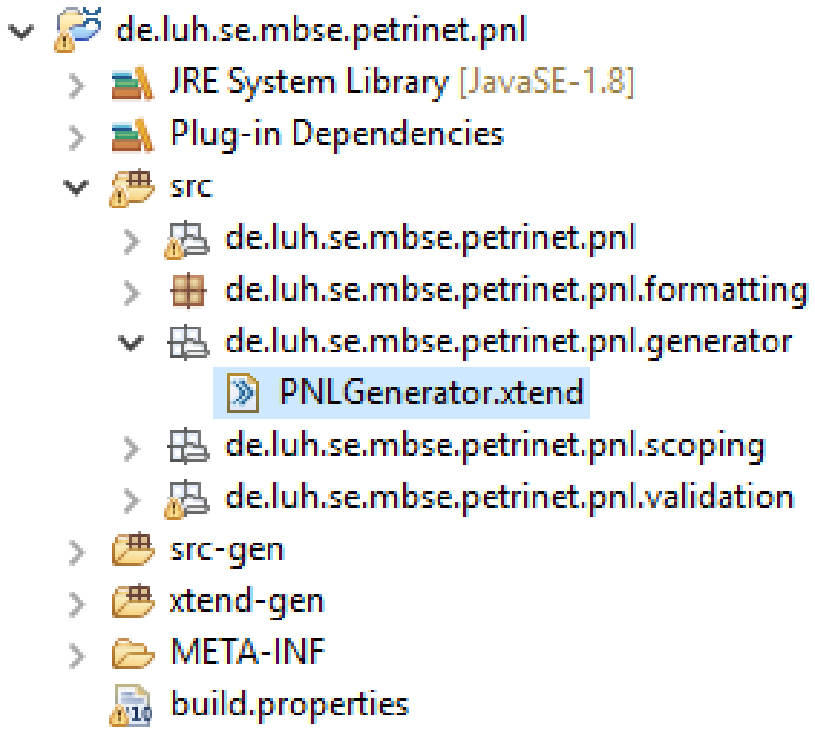



```
public class DayAndNight {
      // places
      int day=1; int night=0;
      // main makeStep method
      public void makeStep(){
            if (canFireSunset()){
                  doFireSunset()
            } else
            if (canFireSunrise()){
                  doFireSunrise()
            } else
            { System.out.println("Cannot fire");}
      }
      // transition's canFire and doFire methods
      protected boolean canFireSunset(){
            return (day > 0);
      }
      protected void doFireSunset(){
            day--; night++;
      }
      protected boolean canFireSunrise(){
            return (night > 0);
      }
      protected void doFireSunrise(){
            night--; day++;
      }
}
```

Xtext and XPand

- Every Xtext project has an empty code generator



Xtext and XPand

- Every Xtext project has an empty code generator

```
10
11 /**
12  * Generates code from your model files on save.
13  *
14  * See https://www.eclipse.org/Xtext/documentation/303_runtime_concepts.html#code-generation
15  */
16 class PNLGenerator extends AbstractGenerator {
17
18     override void doGenerate(Resource resource,
19         IFileSystemAccess2 fsa,
20         IGeneratorContext context
21     ) {
22 //      fsa.generateFile('greetings.txt', 'People to greet: ' +
23 //          resource.allContents
24 //              .filter(typeof(Greeting))
25 //              .map[name]
26 //              .join(', '))
27     }
28 }
29
```

Xtext and XPand

- We can implement our custom code generator for example as follows:

```
22    override void doGenerate(Resource resource,
23        IFileSystemAccess2 fsa,
24        IGeneratorContext context
25    ) {
26        for (pn : resource.allContents.toIterable.filter(Petrinet)){
27            fsa.generateFile(
28                "petrinets/" + pn.name + ".java",
29                pn.compile
30            )
31        }
32    }
33
34    def compile(Petrinet pn){
35        '''
36        package petrinets;
37
38        public class «pn.name» {
39
40            // places
41            «FOR p : pn.element.filter(Place)»
42                «p.compile»
43            «ENDFOR»
44            // main makeStep method
45            public void makeStep(){
46                «FOR t : pn.element.filter(Transition)»
47                    «t.compileForMakeStep»
48                «ENDFOR»
49                { System.out.println("Cannot fire");}
50            }
51
52            // transition's canFire and doFire methods
53            «FOR t : pn.element.filter(Transition)»
54                «t.compile»
55            «ENDFOR»
56        }
57        '''
58    }
```

...