Meta-models and Grammars

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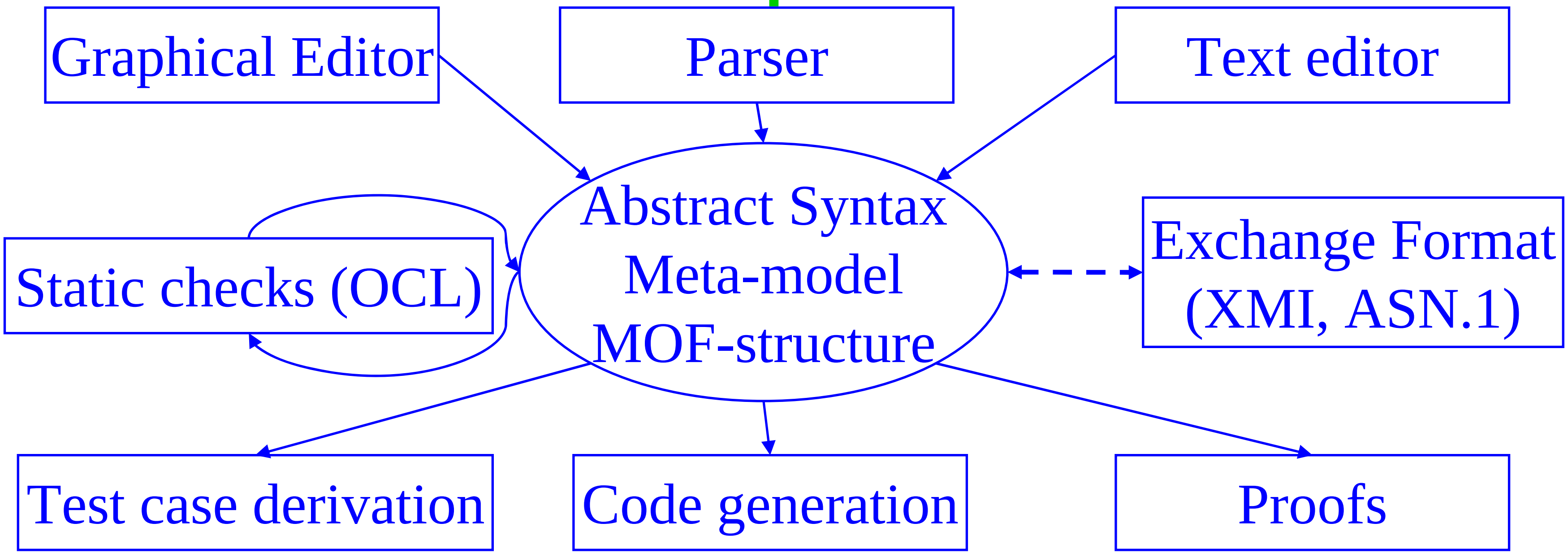
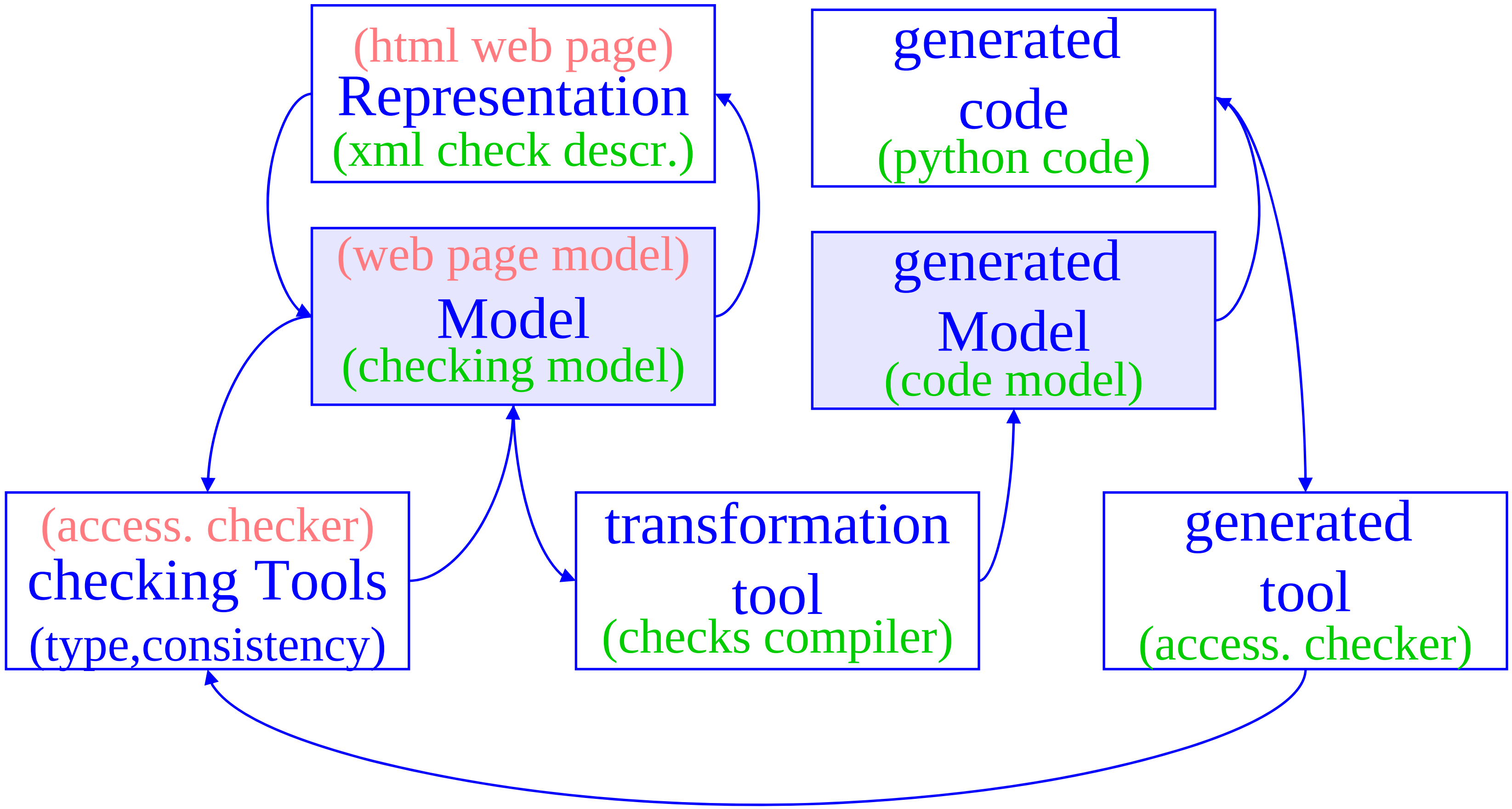
Introduction, Compilers
Modelling & Meta-modelling
Examples
Meta-models vs. Grammars
Summary

Compilers



- Solved: many input/output formats
- Graphical / Domain specific languages, many transformations
- Internal representation: Meta-model vs. Abstract syntax

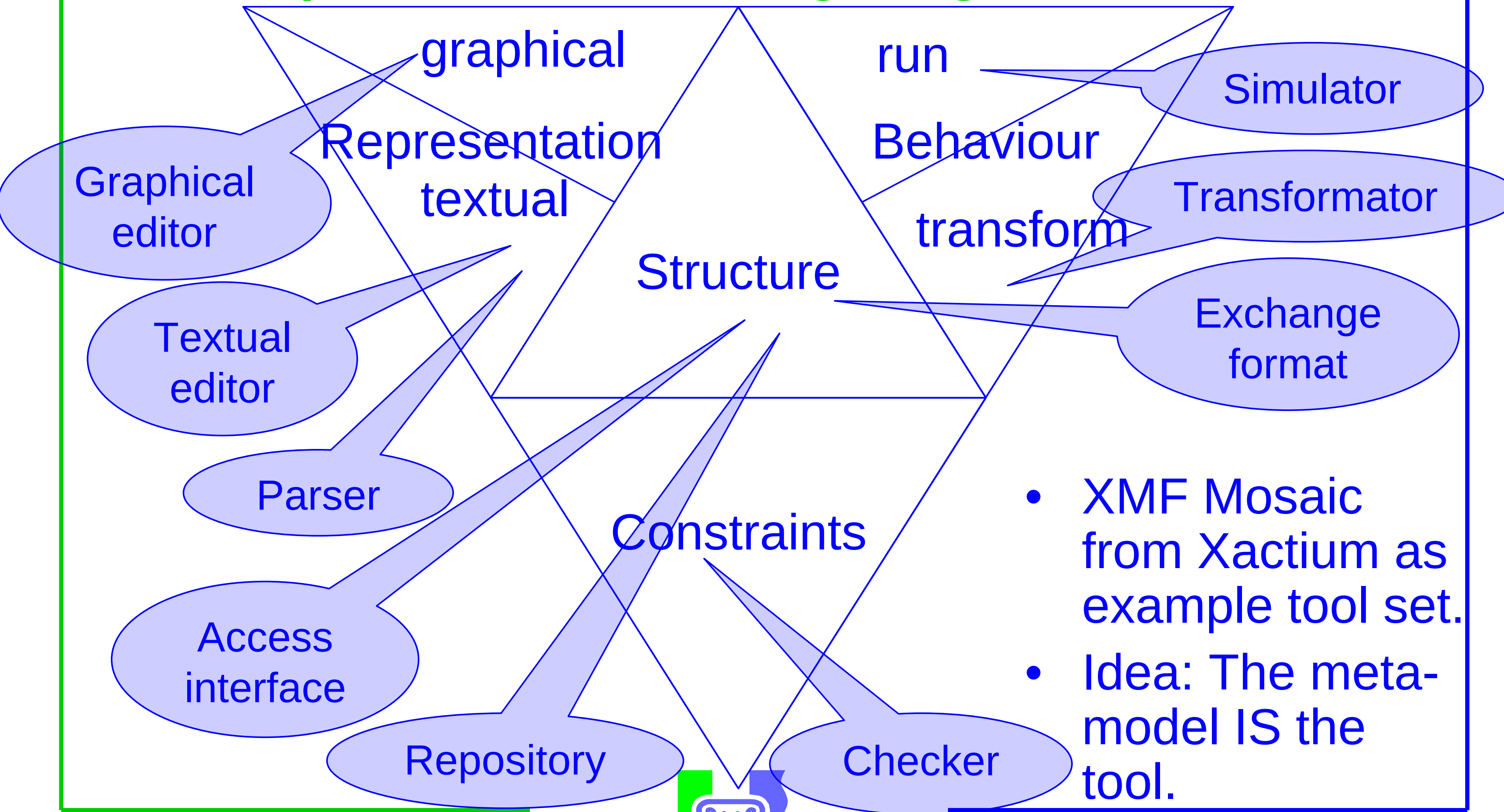
Importance of internal structure



Aspects of Compilers/Languages

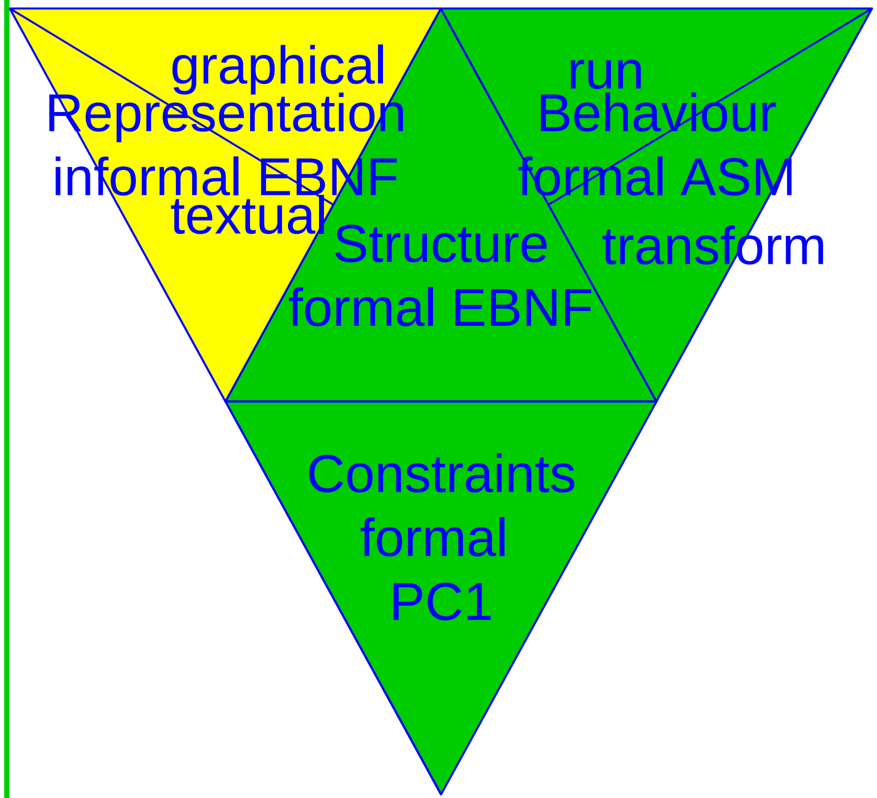
- Language structure: What are the concepts? How are they related?
- Static semantics: additional conditions, what is allowed?
- Representation: How are programs written? -> graphical vs. textual
- Dynamic semantics: What do the programs mean? How to generate code for them?

Aspects of a language & tools

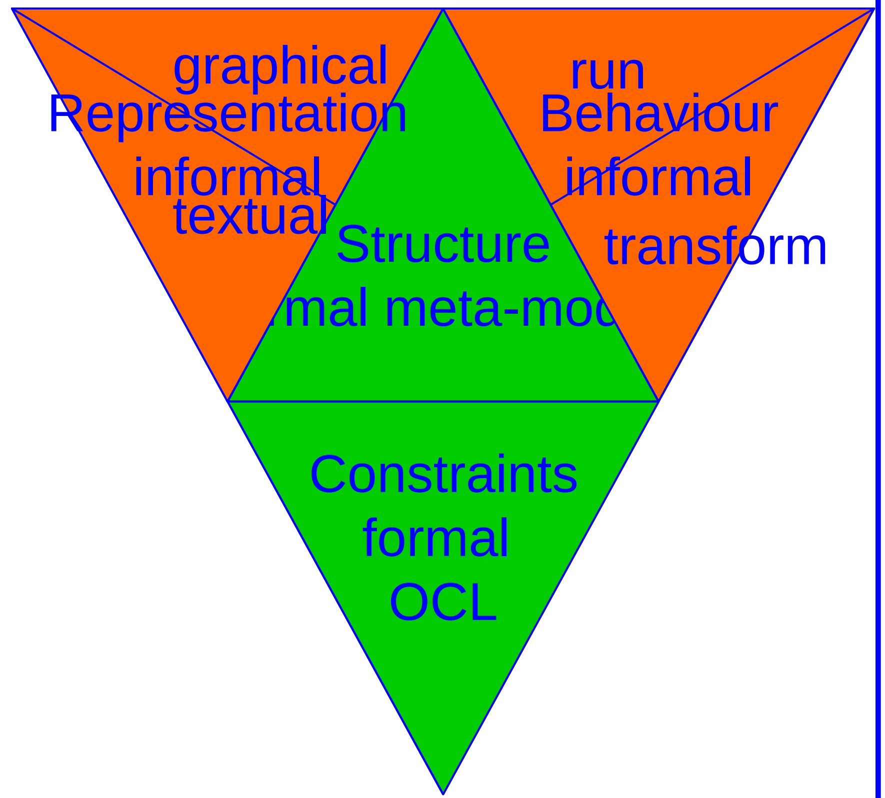


- XMF Mosaic from Xactium as example tool set.
- Idea: The meta-model IS the tool.

Aspects for SDL and UML



SDL



UML

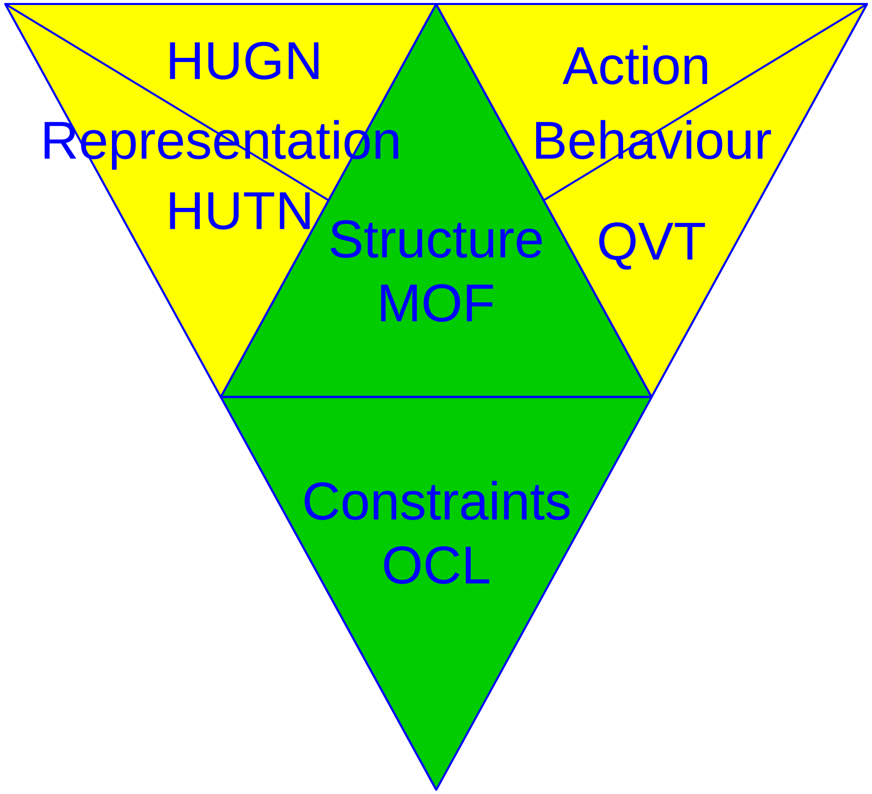
What is a Model?

- A model is an abstraction of a (part of a) system.
  - one model describes several systems, one system can have several models
  - simplified view of a system with respect to criteria
  - can answer questions about the system if related to the view
  - needs a representation, e.g. using a modelling language
- Models on different abstraction levels
  - Models of the real Bits: Assembler
  - Models of the Control Flow: Prog. Lang.
  - Models of data storage: Database descriptions
  - Models of access: Interface languages
- What is the best model of a cat? → It is a cat. But it has to be the same cat!
- A model has aspects like a language.

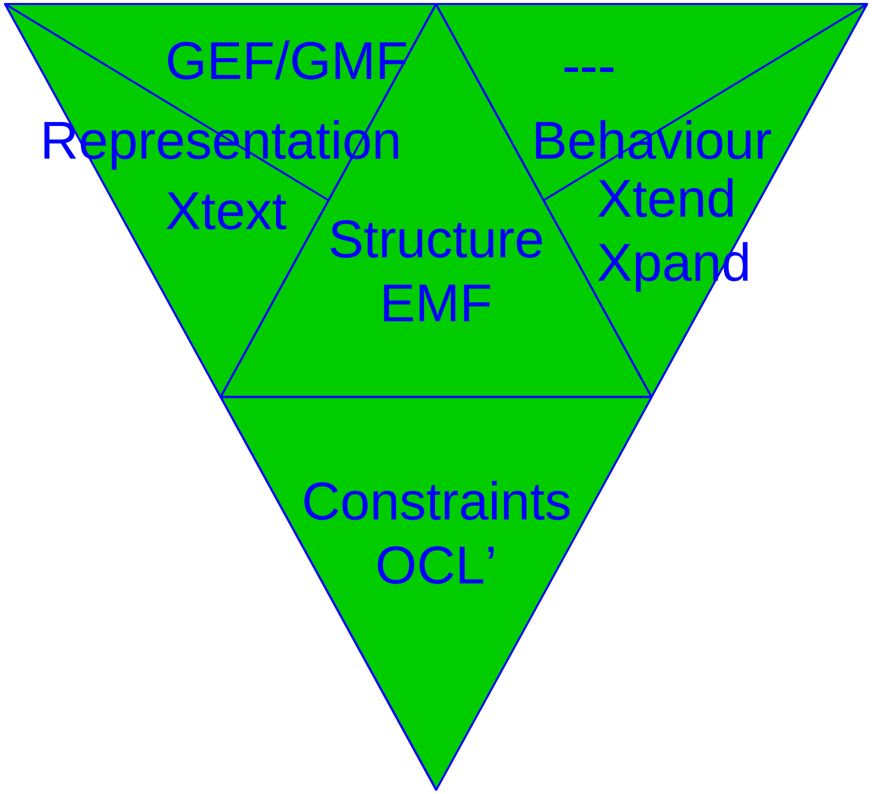
What are Meta-Models?

- A description of a class of models
- Models / high-level descriptions of the modelling language
  - narrow view: structure of the modelling language
  - wider view: all important aspects of the language, i.e. structure, presentation, static and dynamic semantics
- Meta-models (languages) can have several aspects.

Language support MDA and Eclipse

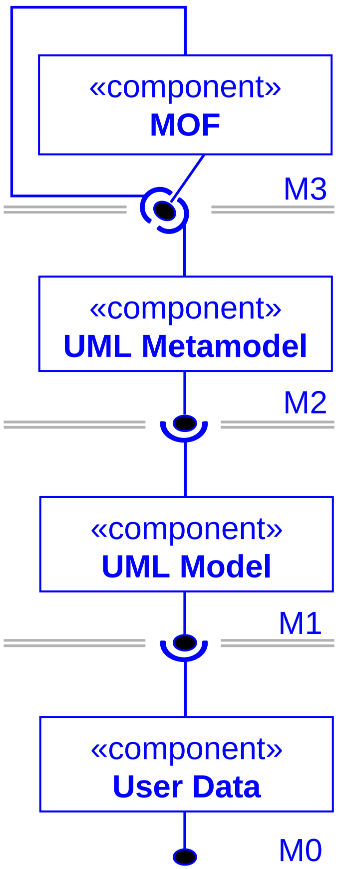


MDA



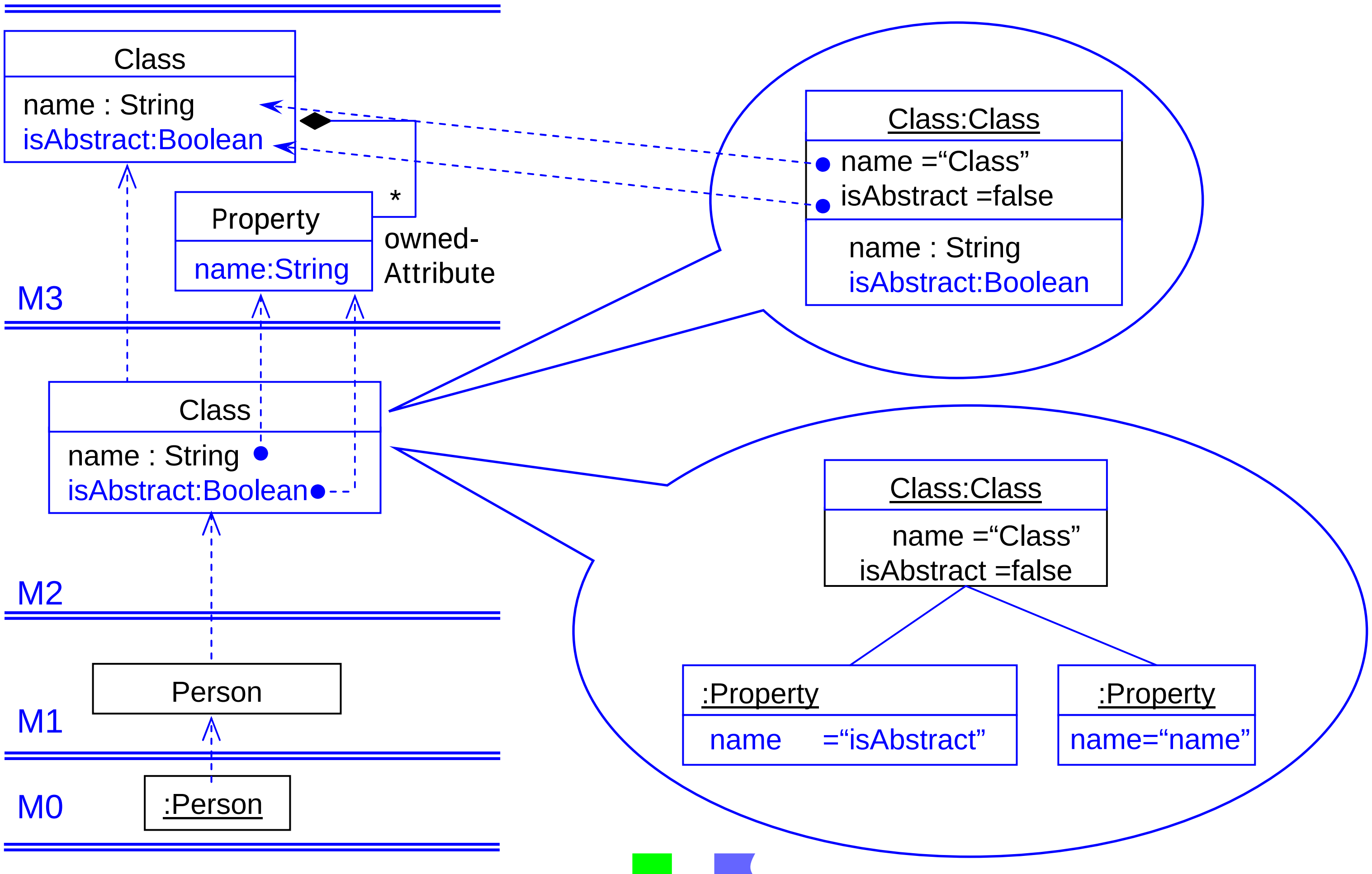
Eclipse (oaw)

A meta-modelling architecture

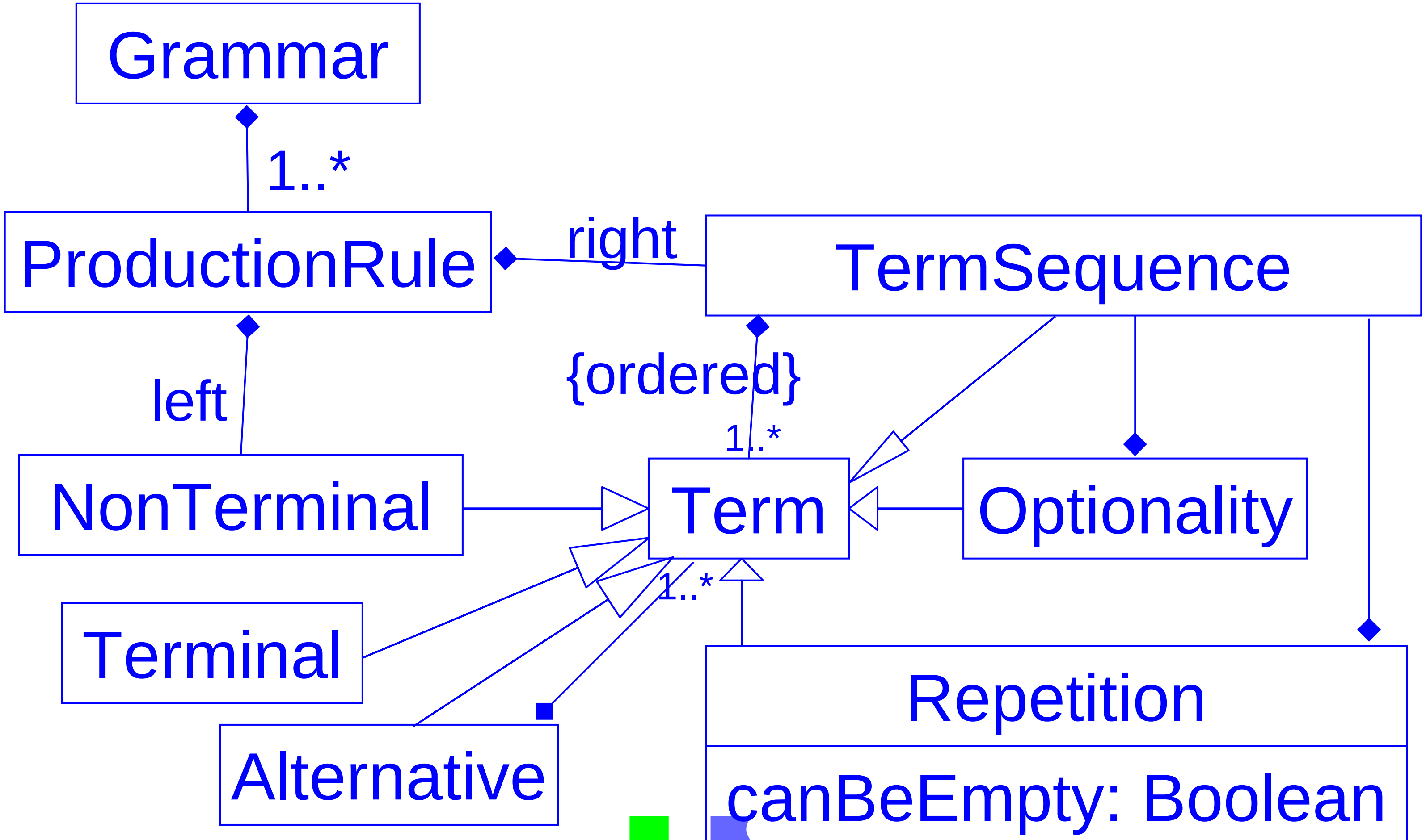


OMG Level	Examples	Grammar example	OCL example
3 = meta meta model	MOF	EBNF	MOF
2 = meta model	UML MM	Java grammar	OCL language
1 = model	UML Model	a program	a formula
0 = instances	real objects	A run	a truth value

Instances on several levels



Simple sample structure



Simple sample constraints

context = Repetition

inv not self.canBeEmpty implies self.exists(TermSequence)

context = NonTerminal

inv theGrammar.ProductionRule.exists (p|p.name = self.name)

Simple sample text syntax

Grammar : {rules=ProductionRule}*;

ProductionRule : left:NonTerminal "::=" right:TermSequence ";";

NonTerminal : name=ID;

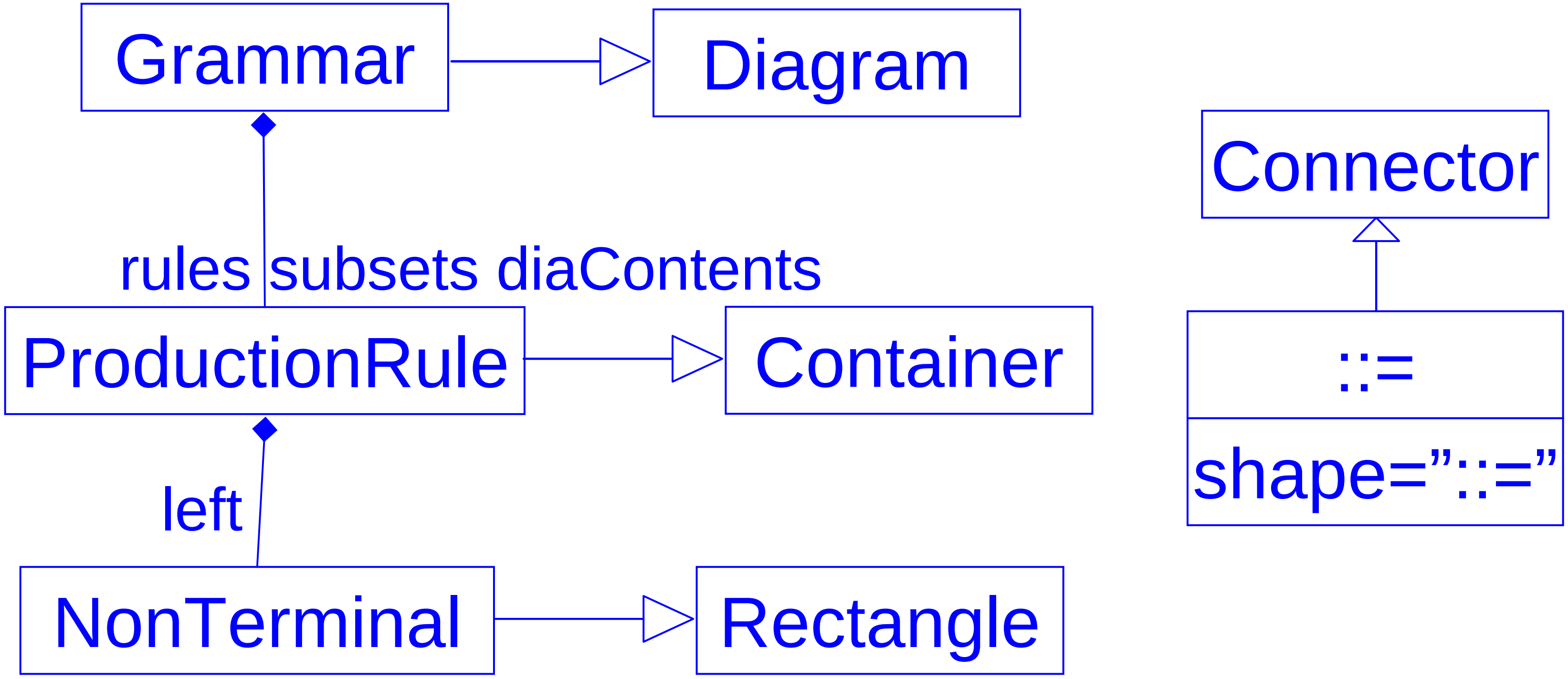
TermSequence : {term:Term}*;

Term : NonTerminal | Terminal | Optionality

Terminal : name=ID;

Optionality : "[" opt:TermSequence "]"

Simple sample graphics



ProductionRule.contents = left –(::=)-> right

Simple sample transformation

removeAlternatives:

ProductionRule(nt, Alternative(set a))

--> set ProductionRule(nt, a)

removeOptional:

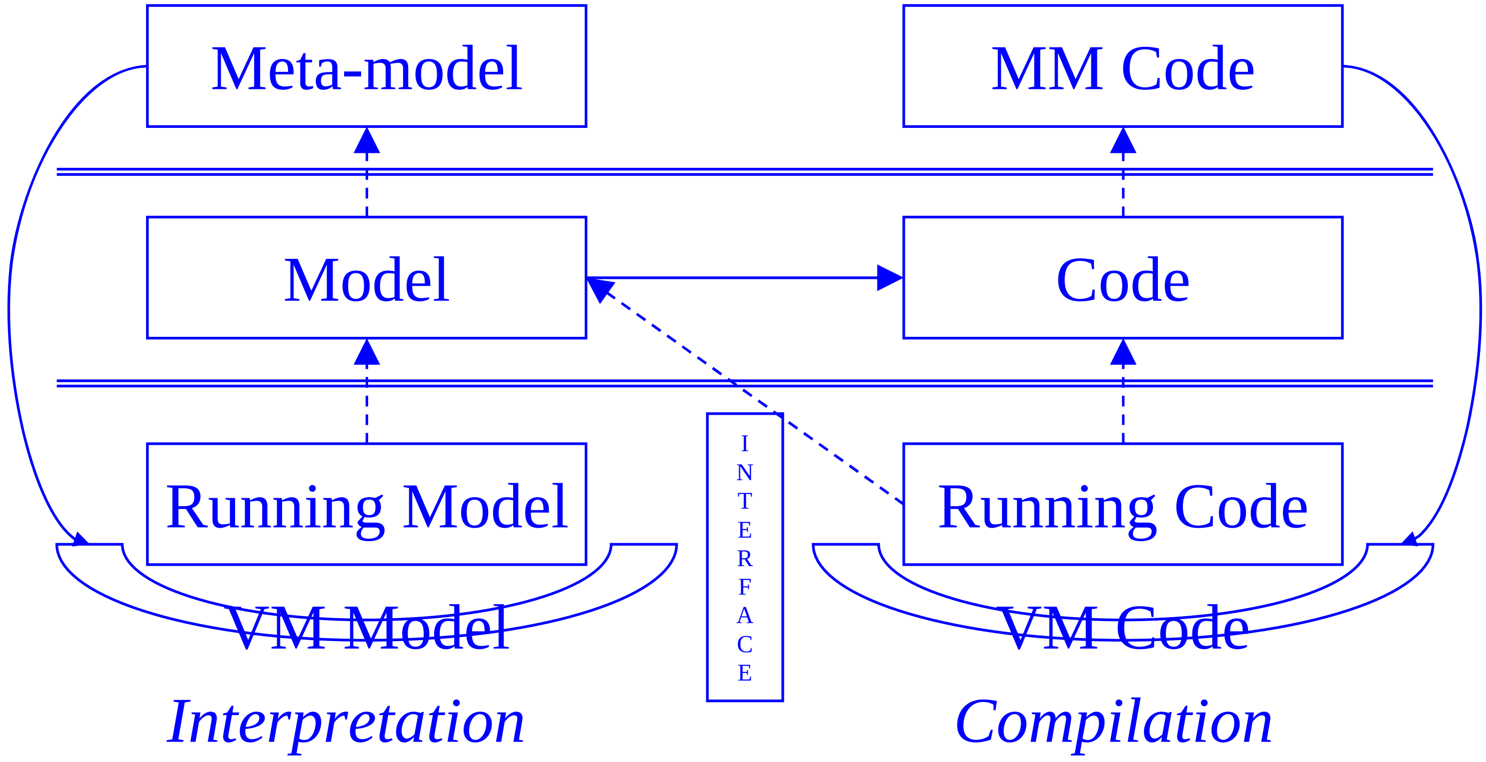
Optional(x)

--> Alternative({x,Nothing})

Simple sample execution

```
Run(a:NonTerminal) =def
  case a.rule of
    NonTerminal: Run(a.rule)
    Terminal: Print(a.rule.value)
    Repetition:
      choose n:Natural
        foreach x:1..n Run(a.rule.sequence)
    Optional:
      choose b:Boolean
        if b then Run(a.rule.term) else Skip
    TermSequence:
      foreach n:1..length(a.rule) Run(a.rule[i])
```

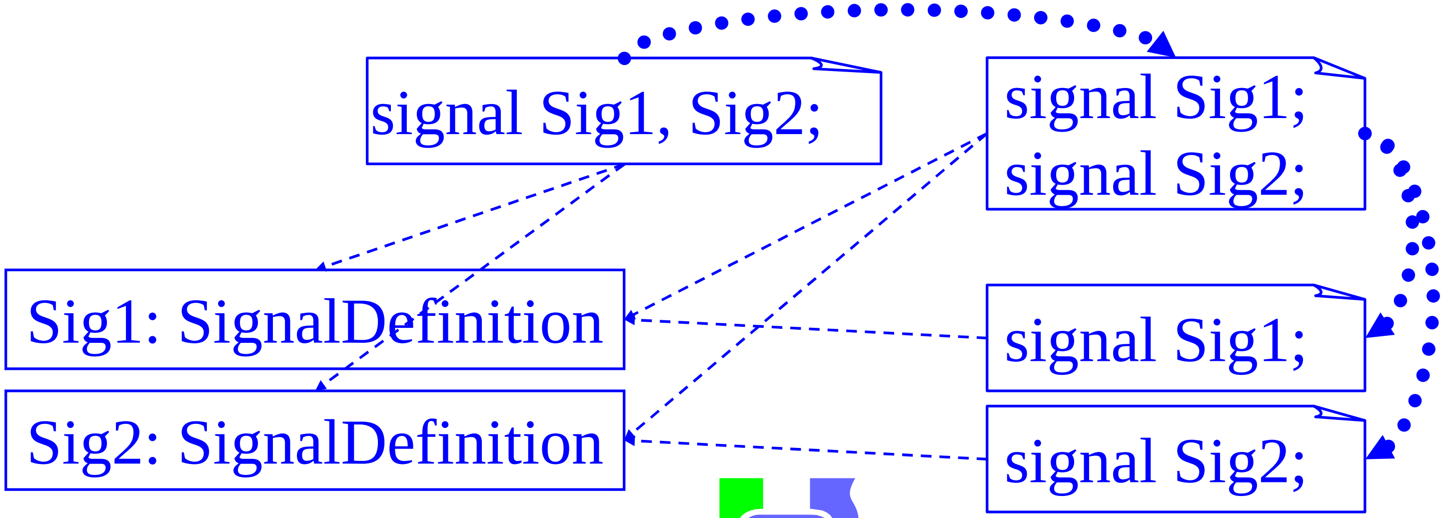
Problem area "runtime"



- Instances of the language: code
- Instances of the program: data / objects

Problem area "representation"

- There are usually several representations for the same meta-model instances.
- Tools and theory exist only for the case 1:1.
- A representation is a separate model that is related to the meta-model.



Meta-models versus grammars

- Advantages of grammars
  - Strong mathematical basis
  - Tree-based
  - Trees can be extended into general graphs
  - Several advanced tools available
  - Easily understandable
- Advantages of meta-models
  - Direct representation of graphs (graphics!)
  - Namespaces and relations between language elements (in particular for language transformations and combinations)
  - Object-oriented definition of oo languages
  - More problem-oriented
  - Reuse and inheritance
  - Tools allow direct handling of models (repositories)
  - Structuring possible (e.g. packages)

Grammars → meta-models

1. Every symbol is represented with a class.
2. A rule with a single symbol on the rhs is represented with an association between the class representing the lhs and the rhs.
3. A rule with a composition on the rhs is represented with an association for every sub-expression.
4. A rule with an alternative on the rhs is represented with a generalization for every sub-expression.
5. A sub-expression consisting of just one symbol is represented with the symbol's class.
6. A sub-expression being a composition or an alternative is represented with a new class with new name. The composition is then handled like a rule.

Using the transformation for SDL

- Joachim Fischer, Michael Piefel, Markus Scheidgen: A Metamodel for SDL-2000 in the Context of Metamodelling ULF in Proceedings of SAM2006
- Introduction of abstract concepts
  - General: namespace, namedElement, typedElement
  - Specific: parametrizedElement, bodiedElement
- Introduction of relations
  - Procedure name versus procedure definition
- Deletion of grammar artefacts
  - Referencing: identifier, qualifier
  - Names in general
  - Superfluous structuring

Conclusions / Summary

- Future languages will be defined using meta-models.
  - definition of good meta-models is difficult
  - need also agreement (standard)
  - patterns for good models needed, maybe joint concepts
- Meta-models / Languages have several aspects: structure, syntax, static and dynamic semantics
- Meta-model language definitions allow tool generation
  - Direct access to the models
  - Easy exchange of representation or several of them
  - Combination of tools handling the language
  - Description of relations between languages
- Meta-models are the models to be used in model-driven compiler technology.